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REPORT No. 2

(America, Great Britain, Dominions and Colonies, China and Japan)

ON THE QUESTION OF THE USE OF CONCRETE AND REINFORCED CONCRETE ON RAILWAYS (SUBJECT I FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

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Figs. 1 to 19, pp. 433 to 474.

A. — Concrete sleepers

Since the ninth Congress (Rome 1922), experiments have been continued and much study given in various parts of the world, covering the subject of reinforced concrete cross-ties (sleepers) for railroad track construction. These experiments have covered many different designs, of which only a few have been satisfactory from a physical standpoint, though length of service is insufficient to draw definite conclusions as to life, and none are recommended for general use, due to high cost. It is apparent that these experiments and studies have failed to develop a reinforced concrete tie which can be considered satisfactory or which can hope to compete with the treated wooden ties now so universally used.

A canvass was made in the form of a questionnaire sent to ninety-nine representative railroads and fifty-six answers were received. These answers are divided between the various geographic sub-divisions as follows :

	Canvassed.	Answered.
Africa	6	2
Argentina . . .	9	5
Australia . . .	3	0
Brazil	3	1
Canada	2	2
Ceylon	1	1
Chili	3	0
China	4	1
Great Britain . .	11	8
India.	11	3
Ireland	5	2
Japan	2	1
Malaysia . . .	1	1
Mesopotamia . .	1	0
Salvador . . .	1	0
United States. .	34	28
Uruguay . . .	2	1

(1) This question runs as follows : « *a*) Investigation into the respective merits of the different designs of concrete sleeper ; *b*) Concrete and reinforced concrete buildings. »

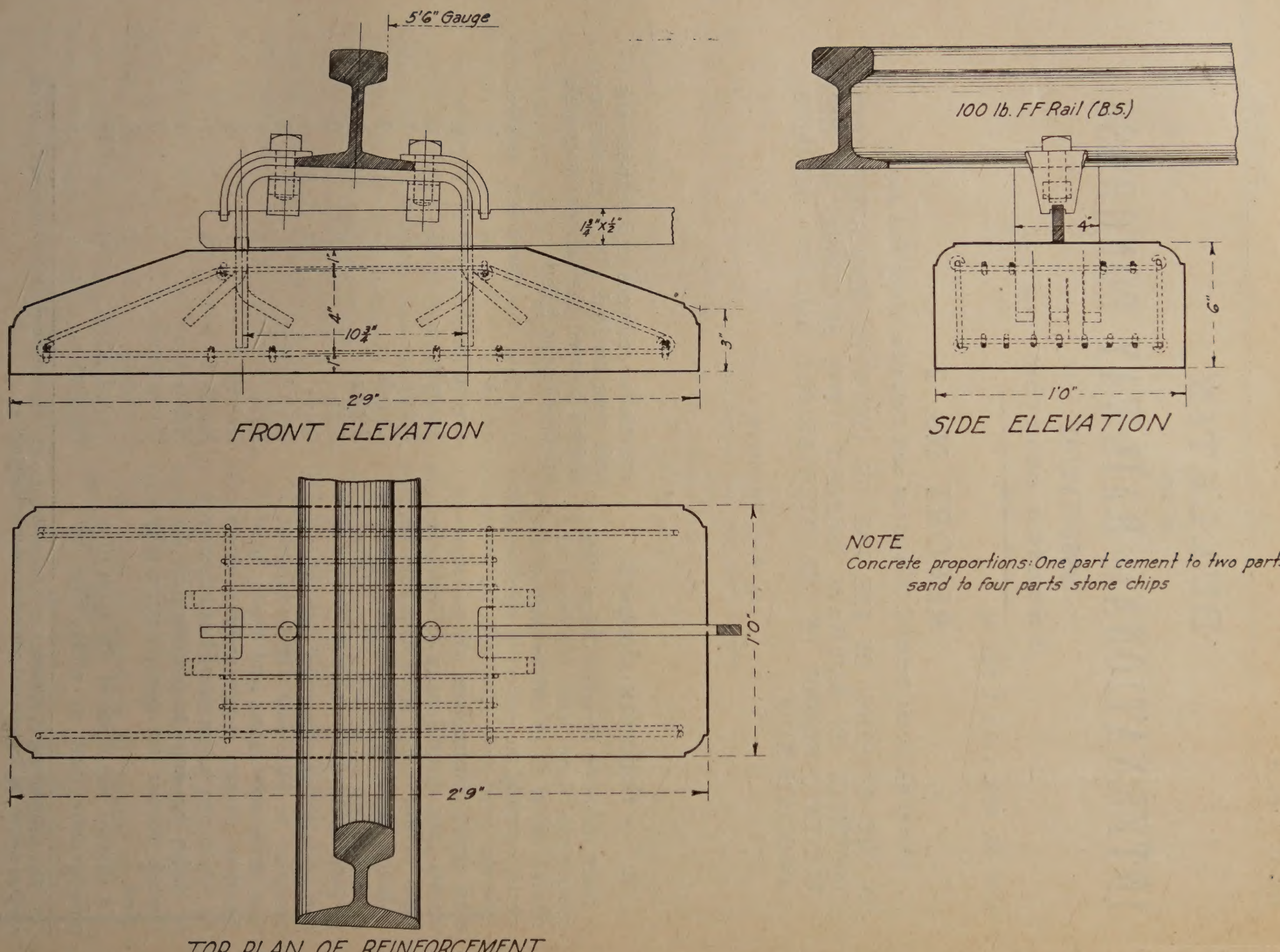


Fig. 1. — Green Moore concrete sleeper, East India Railway.

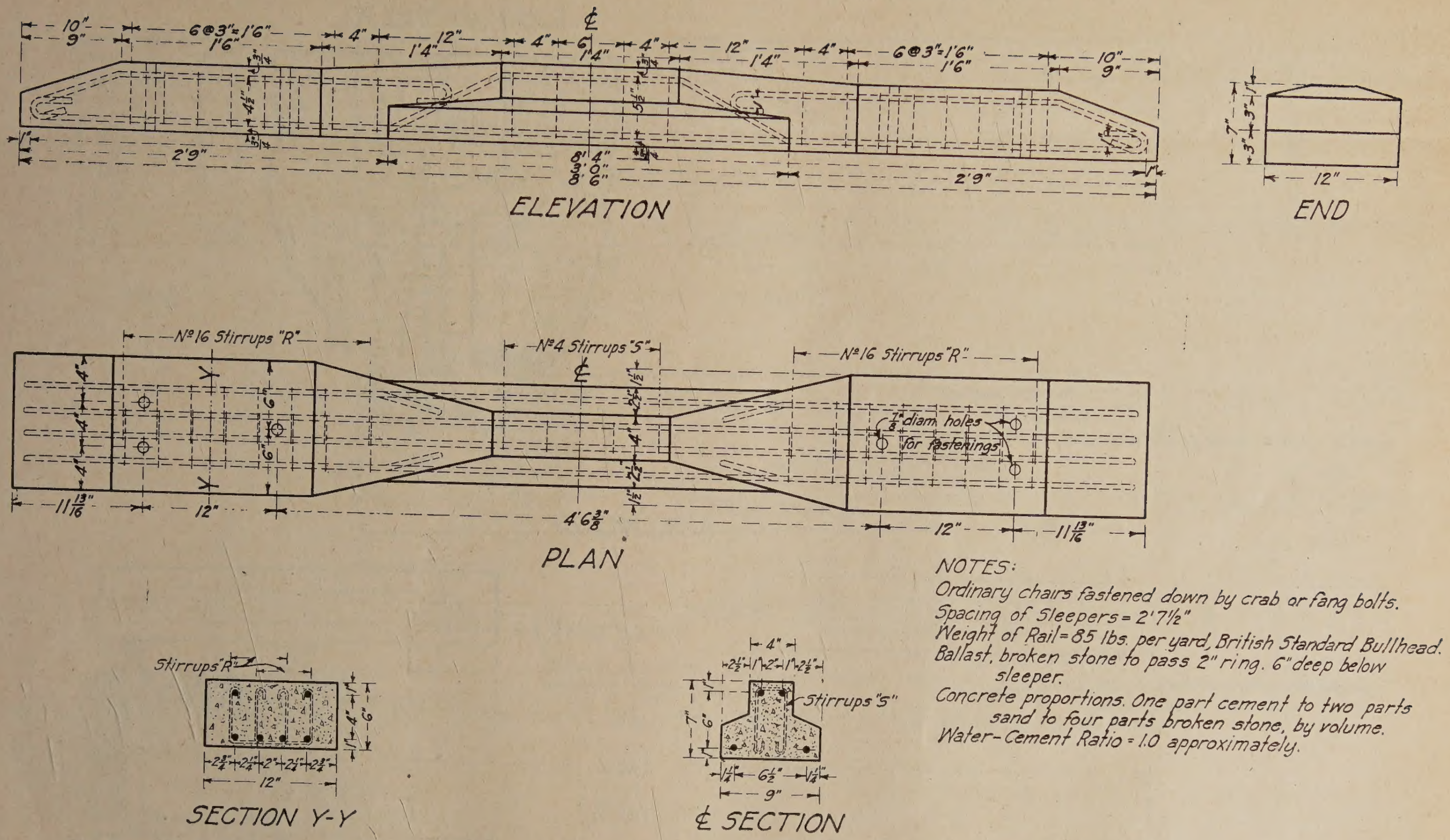


Fig. 2. — M. R. N. C. C. reinforced concrete sleeper (« T » type), London, Midland and Scottish Railway, Northern Counties Committee, Ireland.

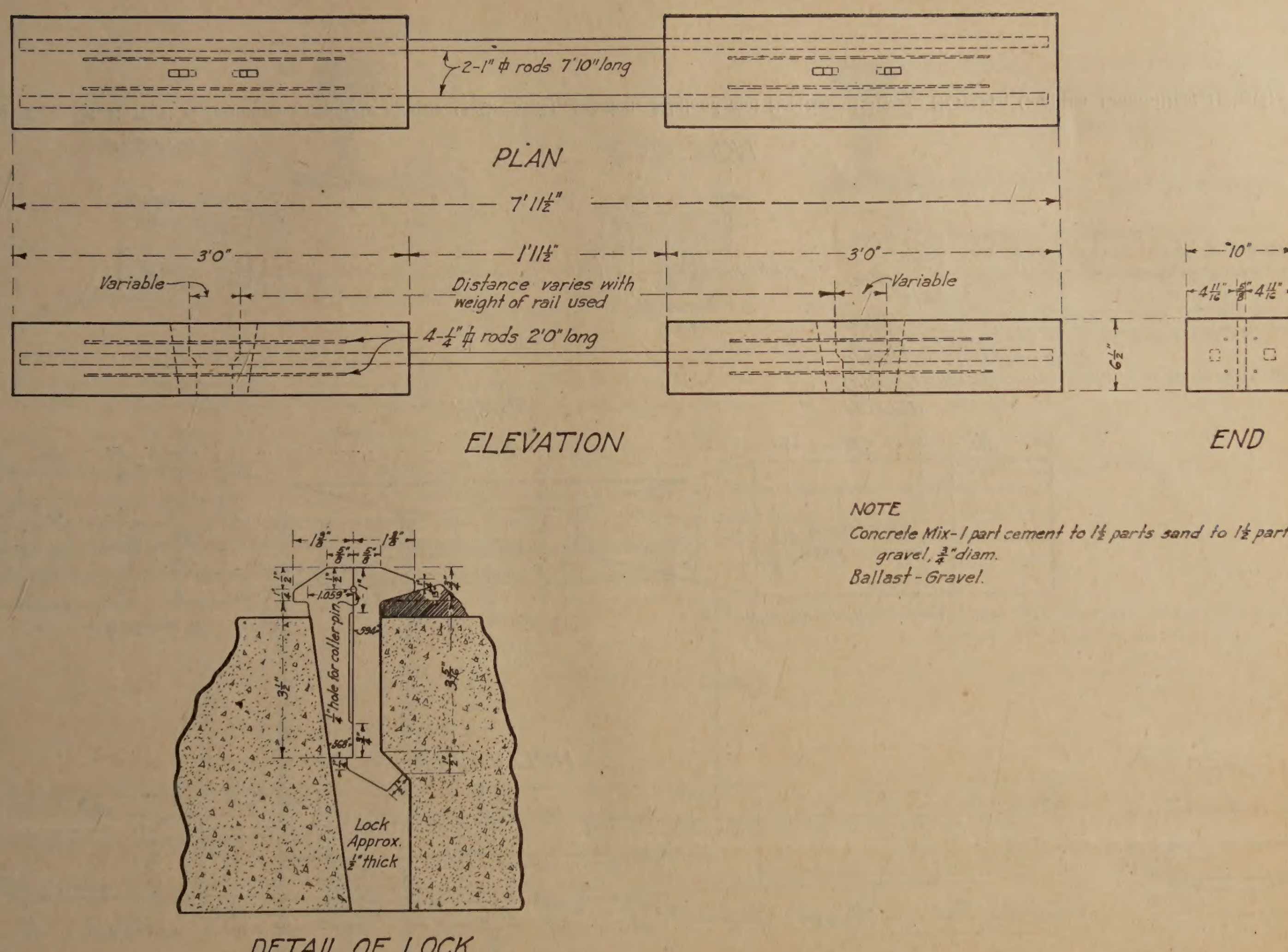


Fig. 3. — « Maine » concrete tie, Bangor and Aroostook Railroad.

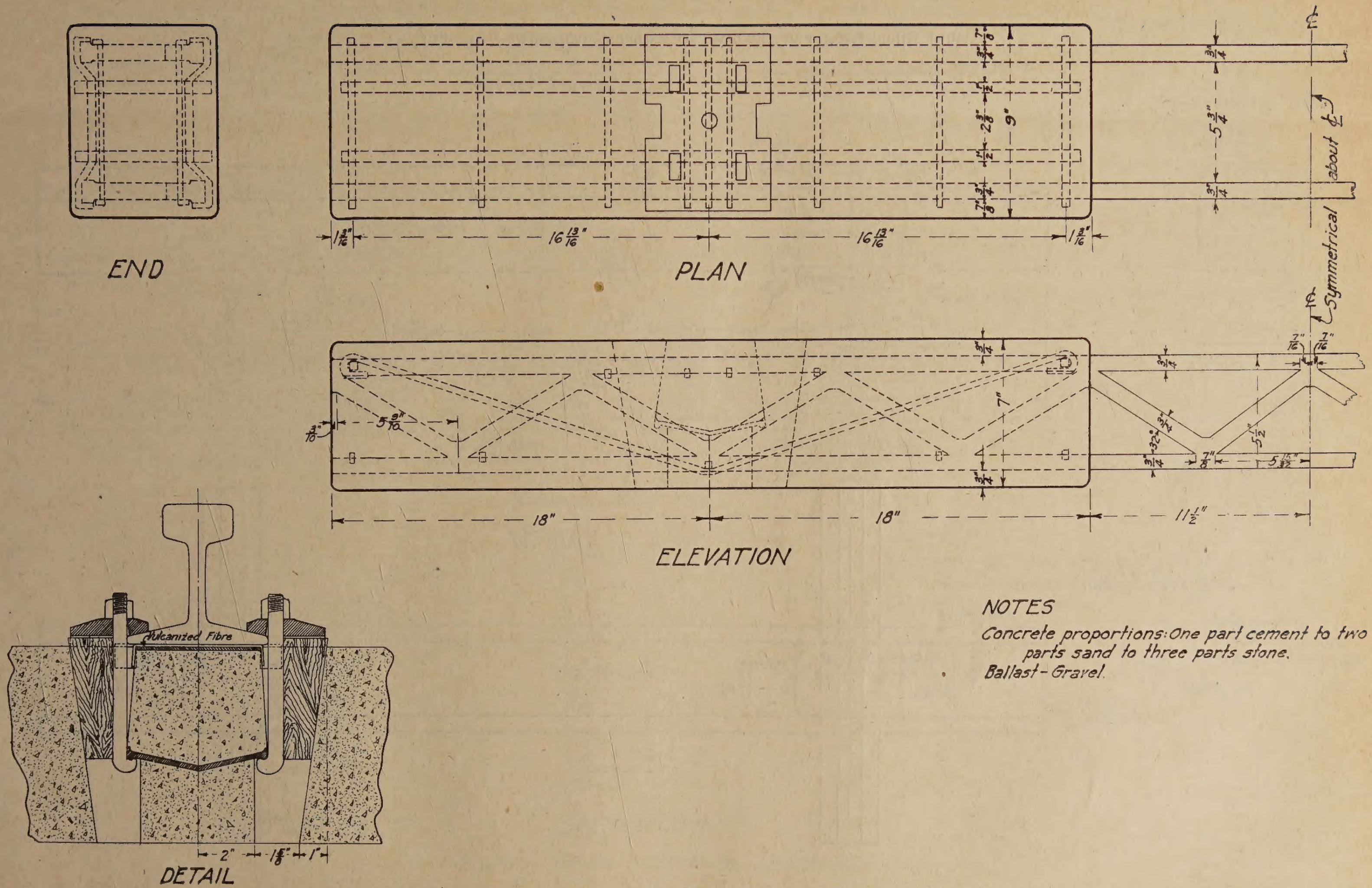


Fig. 4. — « Bates » concrete tie, Elgin, Joliet and Eastern Railroad.

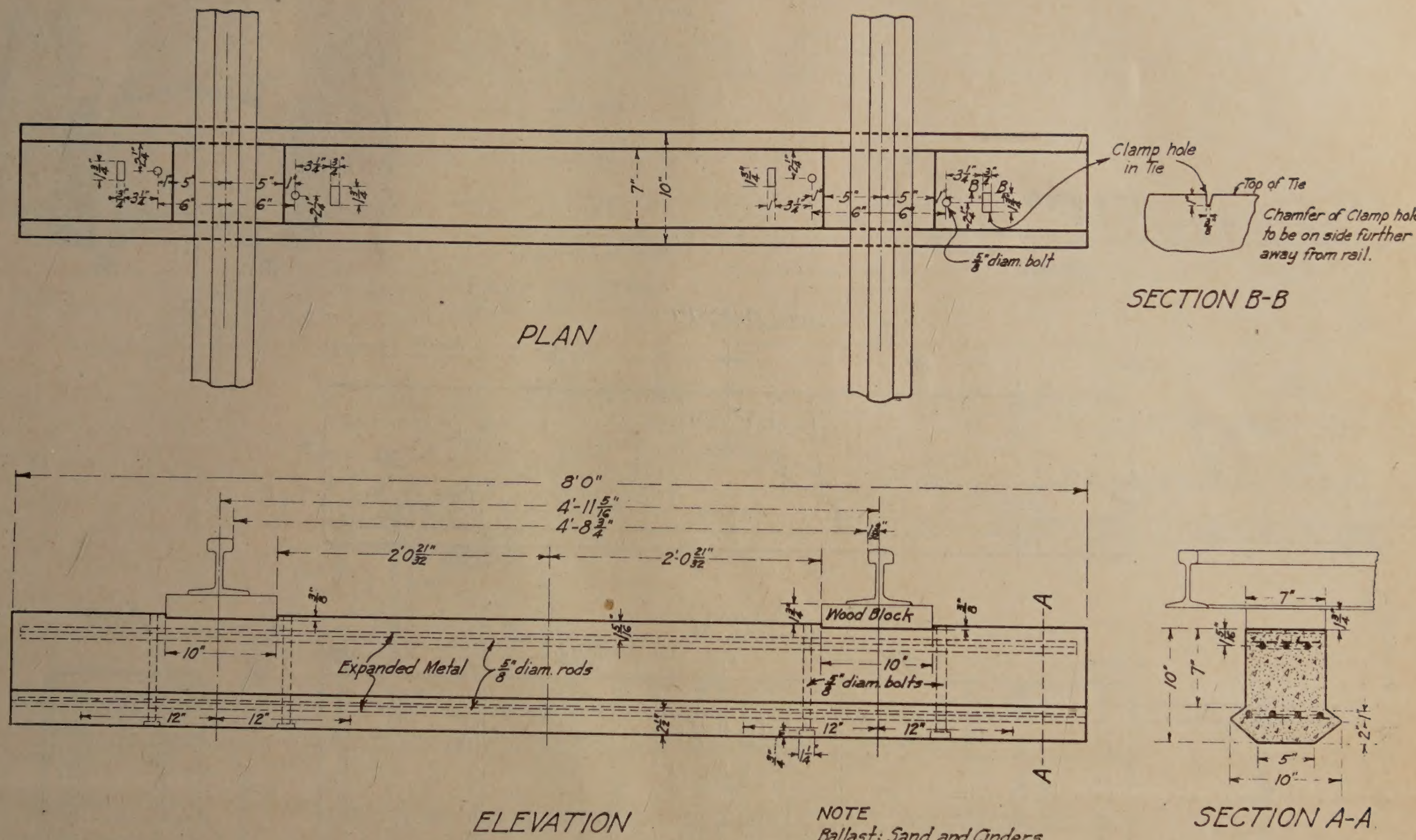


Fig. 5. – American concrete tie, Norfolk and Portsmouth Line.

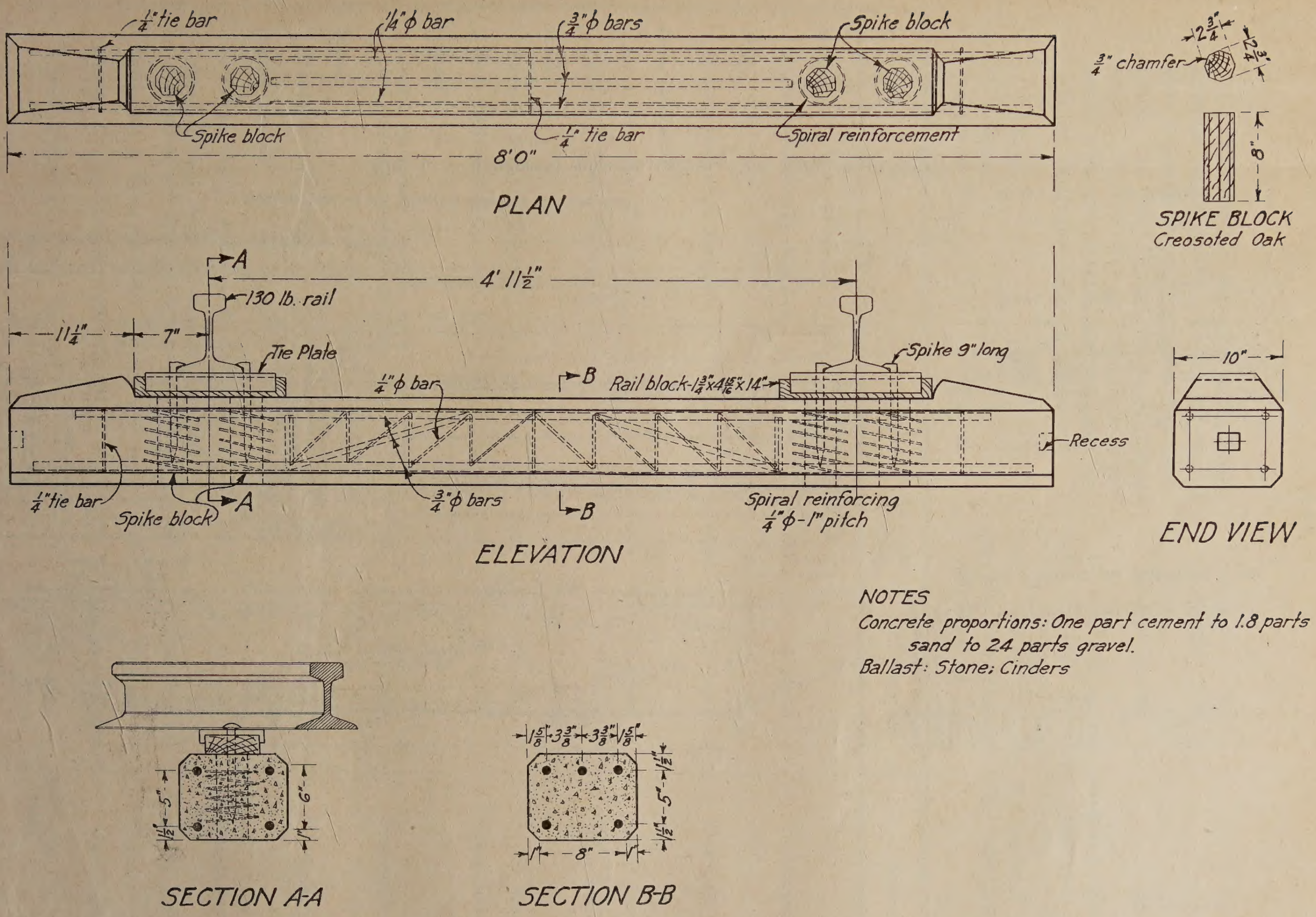
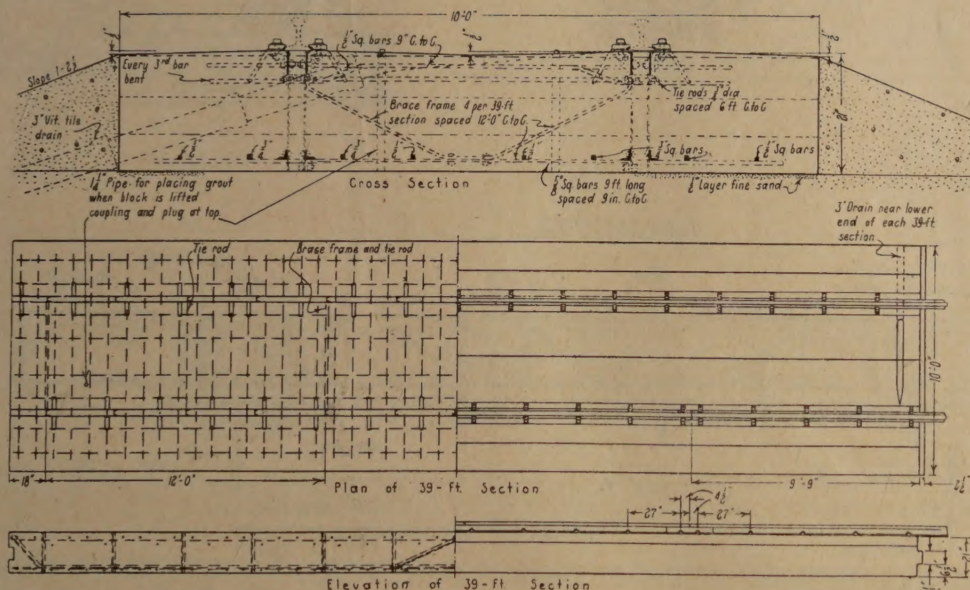
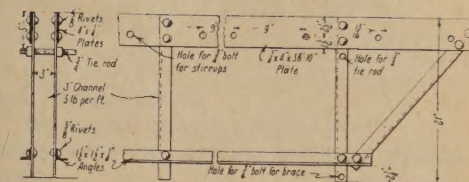


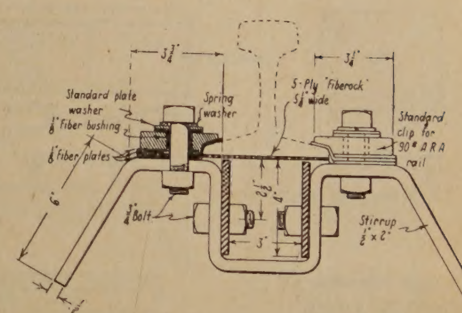
Fig. 6. — « Brown » concrete tie, Pennsylvania Railroad.



General Plan of the Concrete Roadbed Construction



Typical Details of the Reinforcing Truss



Details of the Rail Fastening

Fig. 7. — Reinforced concrete roadbed, Pere Marquette Railway.

Of the fifty-six railroads from which answers were received, twenty-two report that experiments and studies have been made, and thirty-four report no experience. The twenty-two reporting experience with reinforced concrete ties are divided geographically as follows :

Ceylon	1
China	1
Great Britain	2
India	2
Ireland	1
Japan	1
United States	14

In addition to the foregoing, the results of other tests have been compiled and a summary of the results of these tests, divided between the various geographic sub-divisions and railroads, is as follows :

—	*Number of ties.*	*Average life.*	*Result.*
Ceylon.			
Ceylon Government Railway	2 600	4 years.	Unsatisfactory.
China.			
South Manchuria Railway	No data.	No data.	Unsatisfactory.
Great Britain.			
Great Western Railway	196	7 years.	Unsatisfactory.
London & North Eastern Railway	Few.	7 years.	Unsatisfactory.
India.			
Eastern Bengal Railway	Few.	No data.	No data.
East Indian Railway (fig. 1)	Few.	8 years.	Unsatisfactory.
Ireland.			
London, Midland & Scottish Railway (Northern Countries Committee) (fig. 2)	86	11 years.	Unsatisfactory.
Japan.			
Government Railways	150	No data.	No data.
United States.			
Atchison, Topeka & Santa Fe Railroad	180	8 years.	Unsatisfactory.
Atlanta & West Point Railroad, The Western Railway of Alabama; Georgia Railroad.	12	No data.	No data.
Baltimore & Ohio Railroad	30	1 year.	Unsatisfactory.
Bangor & Aroostook Railroad (fig. 3)	69	In service since 1923.	Satisfactory.
Detroit, Toledo & Ironton Railway	50	No data.	Shattered by a derailment.

—	Number of ties.	Average life.	Result.
Duluth & Iron Range Railroad	11	5 years.	Unsatisfactory.
Elgin, Joliet & Eastern Railroad (fig. 4) .	62	In service since 1912.	Satisfactory.
Hocking Valley Railway	Few.	No data.	No data.
Kansas City Southern Railway	27	5 years.	Unsatisfactory.
Lake Erie & Western Railroad	5	17 years.	Unsatisfactory.
Long Island Railroad	33	4 years.	Unsatisfactory.
Los Angeles Railway	4 300	16 years.	Unsatisfactory.
Norfolk & Portsmouth Belt Line (fig. 5) .	138	In service since 1919.	Satisfactory.
Pennsylvania Railroad (fig. 6)	25 000	No data.	No data.
Pere Marquette Railway	1 800	In service since 1902.	Satisfactory except wood blocks need renewal after 12 years.
Southern Pacific Lines	100	11 years.	Unsatisfactory.
Terminal Railroad Association of St. Louis.	10	5 years.	Unsatisfactory.

The above résumé covers physical qualities only, and it is noted that none of the railroads reporting find the concrete cross-tie satisfactory from an economic standpoint, due to their high cost as compared to treated wooden ties. The main objections to concrete cross-ties, in addition to their high cost, seems to lie in their failure to withstand the shock and vibration of heavy traffic, the failure of the fastenings and blocking, lack of insulation between rail and tie, together with gradual weathering and disintegration of the concrete.

A concrete tie to be satisfactory must embody the following requirements :

a) Sufficient strength to withstand the shock and vibration of heavy traffic;

b) A satisfactory fastening for the rail or chair; one that does not require too much attention and is simple and easy in its adjustments. Provision must be made so that shimming between rail and tie can be readily accomplished;

c) Where track circuits are used, adequate and reasonably permanent insulation must be provided between the rail and the tie to insure positive operation of signal system at all times and under varied weather conditions;

d) A roughened surface in contact with the ballast to overcome the lessened frictional resistance of concrete as compared to wood;

e) Provision for anti-creepers properly insulated to prevent leakage of electric current where track circuits are used

and at the same time applied so as not to cause the tie to roll;

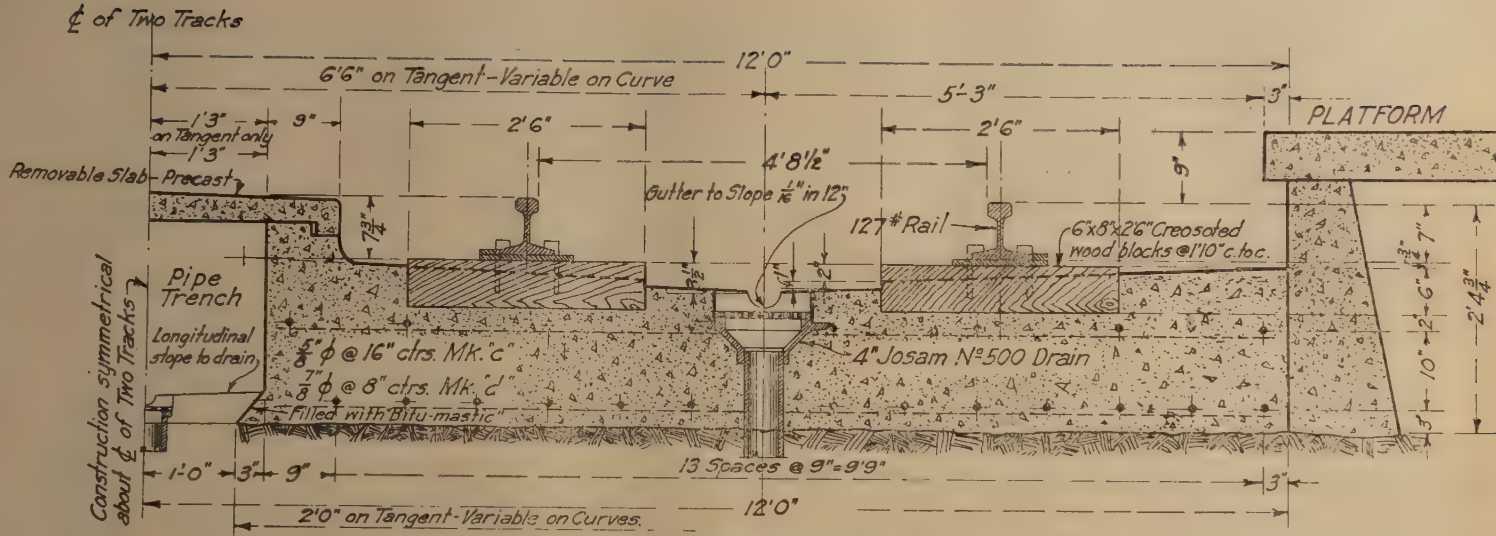
f) A life equivalent or commensurate to that of treated wooden ties to justify use of concrete ties from an economic standpoint. In other words, if the concrete cross-tie costs twice as much as the treated wooden cross-tie, it should have a life approximately twice the life of the wooden cross-tie.

A study of the data submitted for the territory in question indicates that a concrete cross-tie has not yet been tried which will meet the above requirements. It is noted particularly that many railroads report that detail experiments have not been made for the reason that a study of the subject has forced them to the conclusion that with treated wooden ties at their present price, there would be no economy in the use of reinforced concrete. This conclusion is further influenced by the fact that a satisfactory design is not available. It is essential that experiments be continued to develop a satisfactory design. Improvements in materials used and methods of manufacture must be studied to develop longer life, and standardization and quantity production relied upon to secure reduced cost.

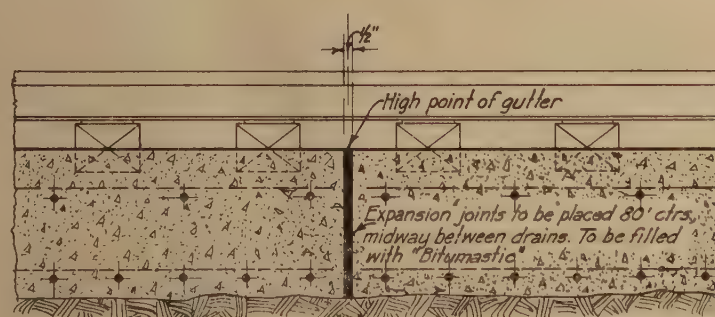
A detail of the canvass is submitted herewith in table I, arranged alphabetically by geographic sub-division, and in table II, arranged alphabetically by trade names of ties used. Details of the many designs of concrete ties that have been experimented with cannot be given, for lack of space, but figures 1 to 6 show details of typical and representative designs, some of which have been favourably reported.

In connection with the report received from the Pere Marquette Railway, mention was made of an interesting experimental installation of reinforced concrete roadbed. Figure 7 illustrates the design. Installation was made in December 1926 and is reported recently as giving satisfactory results. About one-quarter mile of track was constructed at Beech, Michigan. Concrete of 4 000 lb. per square inch strength was used, mixed and placed in accordance with latest specifications based on water-cement ratio theory, using 3-inch to 4-inch slump. The location is one that will impose a thorough service test. The concrete roadbed is in the westbound track of the double track main line between Detroit and Plymouth and will carry all passenger and freight traffic on the Pere Marquette from Detroit to Chicago and points in western and northern Michigan. Santa Fe type locomotives, weighing 321 000 lb. (264 000 lb. on the five driver axles), are used on this section of the railroad. The design of the road-bed is novel in that no cushion is provided between the rails and the concrete substructure. A thin sheet of bituminous felt is placed under each rail, solely to provide insulation and to compensate for minor irregularities in the bearing surfaces of the steel and the concrete. This construction is somewhat in line with the concrete road-bed used with satisfactory results on the New York Central at its terminal in New York City, though the elimination of the wooden blocking and its use for high speed operation presents a novel and interesting departure.

The New York Central reports the recent completion of about three miles of reinforced concrete road-bed as permanent construction at Buffalo, N. Y. Details of this construction are indicated on figure 8. This installation is part of the station improvement for the new « Central » station and was installed pri-



Concrete roadbed detail, typical section.



Longitudinal section of roadbed showing expansion joint.

Fig. 8. — Concrete roadbed, New York Central-Railroad.

marily for sanitary reasons, to facilitate cleaning and reduce maintenance costs. The construction is provided on all of the station tracks and is for slow speed passenger traffic only. The heaviest New York Central passenger equipment will operate over this section; namely, the new « Hudson » type locomotives, 343 000 lb. total weight, with 182 000 lb. on the three driver axles.

SUMMARY AND CONCLUSIONS.

A study of the detail reports received from the various countries indicates that reinforced concrete cross-ties (sleepers) are still in the experimental stage and have not up to the present time proven a satisfactory or economical substitute for treated wooden cross-ties. Insofar as the countries covered in this report are concerned, namely, Africa, Argentina, Australia, Brazil, Canada, Ceylon, Chili, China, Great Britain, India, Ireland, Japan, Malaysia, Mesopotamia, Salvador, United States and Uruguay, while many different designs of reinforced concrete cross-ties have been tried, none have proven entirely satisfactory. However, experiments are being continued covering the sleeper construction as well as the reinforced concrete roadbed, and it is believed that in the light of past experience, a satisfactory design will be evolved. It appears, however, that the use of such construction will have to be for other reasons than economy, except in a few countries where wooden sleepers are scarce or relatively more costly.

TABL

Detail result of canvass arrange

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
Ceylon.			
Baker's timeproof sleeper, Concrete Railway Sleepers Co., Ltd., 2, Deans Yard, The Sanctuary, Westminster, S. W. I.	Ceylon Government Railway.	No data.	No data.
J. J. Finlayson, District Engineer	Ceylon Government Railway.	3 stone, 1 1/4 sand, 1 cement.	No data.
« *Stent's Patent* » *(made in Delhi). D. H. Stent, c/o Messrs. Bird & Co. Calcutta.*	Ceylon Government Railway.	No data.	No data.
China.			
South Manchuria Railway	South Manchuria Railway.	1 cement, 2 sand, 4 stone.	No data.
Great Britain.			
Marriott sleepers	London & North Eastern Railway.	No data.	No data.
Ring type sleeper	London & North Eastern Railway.	No data.	No data.
Stent sleeper	London & North Eastern Railway.	No data.	No data.
Taunton Division, reinforced concrete sleeper.	Great Western Railway.	1 cement, 1 sand, 4 stone.	325 lb.
Yoke concrete block sleeper	London & North Eastern Railway.	No data.	No data.
India.			
Eastern Bengal Railway, concrete tie. . . .	Eastern Bengal Railway.	No data.	No data.
Green-Moore concrete sleeper, L. Green, Esq., c/o Lloyd's Bank, Ltd., Pall Mall, London.	East Indian Railway.	1 cement, 2 sand, 4 stone.	411 lb.

lphabetically by geographical sub-division.

Duration of test or service.	*Result.*	*Remarks.*
Average 2 years.	Used 500 ties under 80-lb. and 88-lb. rail. Few failures. Riding easy and no wear on rail. Mixed traffic.	Manufacture not entirely satisfactory. Reinforcement bars became exposed on surface of sleeper.
Average over 5 years.	Used 1 600 under 80-lb. and 88-lb. rail. Few failures. Riding easy and no wear on rail. Mixed traffic.	Too soon to recommend use of concrete sleepers.
Over 4 years.	Used 500 under 80-lb. and 88-lb. rail. Few failures. Riding easy and no wear on rail. Mixed traffic.	Too soon to advocate use of concrete sleepers.
Recently.	No upheaval due to cold and no destroying due to running of trains.	Not satisfactory — very hard to handle.
9 years.	Used on slow line, but when tried on fast line would not stand express traffic. On slow line ties stood fairly well, except those on each side of rail joint.	Not satisfactory.
Not 6 months.	Concrete broke and crushed—exposed reinforcement.	Not satisfactory.
Less than 1 year.	Used on low and high speed tracks. Freight and passenger traffic.	Not satisfactory.
From 2 to 11 years.	Used 196 ties under 80-lb. and 92-lb. rail on main and branch lines. All ties were failures.	Not recommended.
12 years.	Used on branch and main lines. Concrete blocks none the worse for wear, but tie bars corroded and a number were replaced.	Not satisfactory.
No data.	No data.	Few were used.
8 years.	Few used under 88 1/2-lb., 90-lb. and 100-lb. rail. Subject to heavy loads and high speed. Some removed due to breaking. Gave excellent running. Not used as standard.	More expensive to install due to greater weight and hard to handle. Require less attention. When first used after the war were economical, but now first cost is higher than wood ties. Saddle is the weakness of Green-Moore tie.

TABLE I.

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
Ireland.			
M. R. N. C. C. reinforced concrete sleeper .	London, Midland & Scottish Railway, Northern Counties Committee.	1 cement, 2 sand, 4 stone.	Type « O », 545 lb. Type « T », 553 lb.
Japan.			
Fukagawa type	Government Railways.	1 cement, 2 sand, 4 gravel.	372 lb.
United States.			
American concrete tie, originally known as the « Dickey Tie ».	Norfolk & Portsmouth Belt Line.	No data.	673 lb.
American concrete tie, originally known as the « Dickey Tie ».	Norfolk & Portsmouth Belt Line.	No data.	673 lb.
American concrete tie, originally known as the « Dickey Tie ».	Norfolk & Portsmouth Belt Line.	No data.	673 lb.
A. J. Bates concrete tie	Elgin, Joliet & Eastern Railway.	1 cement, 2 sand, 3 stone.	453 lb.
Buhrer concrete tie	Lake Erie and Western Railroad.	No data.	No data.
« Casey » concrete tie, Concrete Tie Co., Pittsburgh, Pa.	Pennsylvania Railroad (Central Region).	No data.	600 lb.

(continued.)

Duration of test or service.	*Result.*	*Remarks.*
Average 11 years.	Used 86 under 85-lb. rail. Freight and passenger service. Slow and high speed.	No failures in 36 ties of the 86 installed. Those that failed seemed to be poorly mixed. Recommend concrete ties only when they become an economic proposition due to increased cost of timber.
About 2 years.	Used 150 under 60-lb. rail. Installed March 1927. Low speed freight traffic. 5 % of total number installed failed due to defective workmanship. Smooth riding.	Track keeps better alignment. Principal defect lies in difficulty of fastening rail, but this type overcomes that trouble.
6 years.	Used 18 ties under 85-lb. rail on yard tracks and heavy switching service. Installed 4 June 1919. Ties in good condition 6 October 1925.	Should last indefinitely.
2 years.	Installed 100 ties 18 September 1923. By 6 October 1925 nine were broken due to not being built according to specification. Remaining 91 in good condition and giving good service. Used on heavy freight service exclusively.	Giving good service.
2 years.	Installed 20 ties 20 October, 1923. 6 October, 1925 all were in good condition and giving good service. Used on heavy freight service exclusively.	Giving good service.
17 years.	Used 62 ties under 85-lb. rail. Heavy freight service. No failures. More solid riding. Installed May 1912. All in service on 29 June 1928.	Make no recommendations at this time.
20 years.	Installed 5 ties in August 1903. By August 1923 they were all in very bad condition. Removed on 18 June 1924.	...
3 years.	Used 510 under 130-lb. rail on heavy freight service. Installed in 1925 and are still in service 27 September 1928 except 46 which failed due to breaking.	...

TABLE I

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
« Casey » concrete tie (revised design). « Brown » Concrete Tie Company, Pittsburgh, Pa.	Pennsylvania Railroad (Eastern Region).	1 cement, 1.8 sand, 2.4 gravel.	600 lb.
Chamberlin concrete tie	Terminal Railroad Association of St. Louis.	No data.	No data.
Duke reinforced concrete tie	Atlanta & West Point Railroad Co. Western Railway of Alabama, Georgia Railroad.	No data.	No data.
Hanna cement tie	Atchison, Topeka and Santa Fe Railroad.	No data.	450 lb.

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ration of test or service.	*Result.*	*Remarks.*
1 1/2 years.	Installed 3 006 ties in freight track in July 1927 under 130-lb. rail. Heavy service. On 10 April 1928, 40 ties showed tension cracks, not serious. 11 ties showed serious cracks, breaks or crushing.	...
	Installed 1 486 ties in freight track July 1927 under 130-lb. rail. Heavy service. In April 1928, 70 ties showed slight tension cracks, not serious. 16 ties showed serious cracks, breaks or crumbling.	...
	Installed 517 ties in main track July 1927 under 130-lb. rail. Heavy service, exclusively freight. On 3 May 1928, 29 ties showed slight tension cracks, not serious. 12 ties showed serious breaks and cracks.	...
	Installed 970 ties in main single track July and August 1927 under 130-lb. rail. Heavy mixed traffic. In May 1928, 21 ties had developed serious cracks or fractures.	...
	Installed 1 986 ties in main single track under 130-lb. rail in July and August 1927. Mixed heavy service. In May 1928, 22 ties had developed serious cracks or fractures.	...
	Installed 1 993 ties on main single track in July and August 1927 under 130-lb. rail. Heavy mixed traffic. In May 1928, 21 had developed serious cracks or fractures.	...
5 years.	Used under 80-lb. rail. Light switching yard service. 10 put down in 1920. Taken up 1925.	Badly broken up.
Several years.	Used 12 under 90-lb. rail on main track, high speed freight and passenger. Put in 20 June 1927.	Good service.
11 years.	Used 8 ties on main track. Installed 21 November 1912 and removed 4 January 1924. All were broken through under one or both rails.	Failed to hold track in surface as well as wood ties.

TABLE I

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
Hatch tie	Duluth & Iron Range Railroad.	1 cement, 2 sand, 2 1/2 stone.	630 lb.
Ickes concrete tie, Chanute, Kansas . . .	Atchison, Topeka & Santa Fe Railroad.	No data.	No data.
The American Concrete Tie Co.	Kansas City Southern Railway.	No data.	Type I, 690 lb. Type II, 679 lb. Type III, 716 lb.
Kimball concrete tie	Pere Marquette Railway.	No data.	No data.
King foreign concrete tie	Long Island Railroad.	No data.	No data.
Maine Concrete Railroad Tie Co., Corrina, Maine.	Bangor & Aroostook Railroad.	1 cement, 1 1/2 sand, 1 1/2 gravel (3/4 inch diameter).	443 lb.
McDonald concrete tie	Atchison, Topeka & Santa Fe Railroad.	No data.	No data.
	Los Angeles Railway.	No data.	306 lb.

ntinued.)

ration of test or service.	*Result.*	*Remarks.*
5 1/2 years.	Used 11 ties under 80-lb. rail, slow speed, heavy traffic, freight track. Installed in August 1923. None have failed to date 12 October 1928.	Four show signs of disintegration of the concrete. Do not advocate using them.
3 1/2 years.	Used 7 ties on passenger sidetrack. Installed 8 December 1915. Last one removed 27 June 1919. All failed by breaking up.	Do not hold track in surface as well as wood ties.
early 8 years.	Used 27 ties in main line track in 1921. 17 failed in short time and were replaced in October 1922 on an industry spur. By 1 August 1924, 6 were cracked through the center, 2 near the bearing surface, and 2 more were cracked elsewhere. Used under light traffic and 80-lb. rail.	Design of Ickes ties has been modified since last installed. Cost of concrete tie can not be justified as compared with wood tie.
27 years.	Used 1 800 under 75-lb. and 90-lb. rail. Installed in 1901 and 1902. Slow speed passenger service.	...
4 1/2 years.	Used 33 ties under 100-lb. rail. Put in service June 1924. Slow speed passenger service.	...
5 years.	Used under 85-lb. rail on high speed, heavy passenger and freight service. 10 ties were installed on 11 December 1923. The ties were interlaced with cedar ties. On 30 August 1924 the cedar ties were removed and 59 additional concrete ties put in. On 30 May 1928 all were in service. No failures to date.	Not advocated, due to cost, even with long life, being more than cedar tie.
6 1/2 years.	Used 21 ties in main track. Installed June 1907 and all were removed before 15 December 1913.	Will not hold track in surface as do the wood ties.
16 years.	Used under 87-lb. rail on high speed heavy passenger service. In July 1911, 4 323 were put in service. By 11 July 1925, 40 were removed due to installation of special work. On account of reconstruction of track by 11 August 1927 only 736 remained, others replaced by creosoted pine ties. 736 ties remained 11 June 1928.	Construction was very expensive and did not stand up well. Maintenance heavy. Not recommended.

TABLE I.

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
Moore concrete tie, S. B. Moore	Southern Pacific Lines.	No data.	No data.
Percival concrete tie	Southern Pacific Lines.	No data.	No data.
Riegler concrete tie	Pennsylvania Railroad (Central Region).	No data.	No data.
Santa Fe concrete tie (Santa Fe Test, Topeka).	Atchison, Topeka & Santa Fe Railroad.	No data.	405 lb.
Saxon concrete tie, Plastic Railroad Tie Co., Tecumseh, Oklahoma.	Atchison, Topeka & Santa Fe Railroad.	No data.	No data.
Southern Pacific, concrete tie	Southern Pacific Lines.	No data.	No data.

(Continued.)

Duration of test or service.	*Result.*	*Remarks.*
5 years.	In January 1917, 40 ties were installed. On 8 August 1922, 38 remained. All were removed in November 1922 due to poor bond between concrete and steel reinforcement and ineffectiveness of fastening.	Many years before concrete ties will be of economic use compared to wood ties, due to large available supply of timber.
17 years.	53 ties were installed 1906. In 1914, 2 ties removed due to breaking. In 1915, 3 ties removed (1 broke and 2 had broken screw spikes due to relaying rail). In 1918, 16 ties were removed due to breaking and again 1 was removed in 1919 for same reason. On 8 August 1922, there remained 26 ties, all of which should have been removed, faulty screw spikes. By 16 October 1923 all were removed.	...
20 years.	Used 15 ties under 85-lb. rail in May 1908. Installed on track Cl. 1, through and suburban passenger service. In 1910 used under 100-llb. rail. In December 1914 placed in track Cl. 3, freight and through passenger service. On 31 October 1921 changed to 130-lb. rail. During 1926 and 1927, 7 were repaired due to crushing on one end. On 26 August 1927 all 15 ties were in service. Test closed 11 June 1928.	...
About 4 years.	Used 6 ties in south lead of Topeka Yard about October 1911 or early in 1912. Last tie removed 5 October 1915. All failed due to breaking.	Will not hold track in surface as well as wood tie.
3 years.	Used 14 ties on main line tracks. Installed in August 1913. 9 ties broke up and were replaced prior to 7 August 1914. 19 ties of a larger size but same pattern installed in May 1914. Prior to 16 April 1917 all these ties were removed due to failure.	Do not hold track in surface as well as wood tie.
From 1 1/2 to 12 years.	Used a few ties in a light service branch line and are still in serviceable condition. 100 ties were placed in heavy traffic main line service, but in 18 months time had to be removed due to bad condition of oak blocks used to fasten rails. Ties cracked in the middle and some disintegration occurred under rail seat.	It will be some time before concrete tie will be of economic use compared to wood tie due to large available supply of timber.

TABLE I.

NAME AND MANUFACTURER.	*Used by.*	*Proportion.*	*Weight.*
Southern Pacific — Santa Fe concrete tie .	Southern Pacific Lines. Santa Fe.	No data.	No data.
U. S. Indestructible concrete tie	Detroit, Toledo & Ironton Railroad.	No data.	No data.
U. S. Indestructible concrete tie	Southern Pacific Lines.	No data.	No data.
Waller & Reece concrete tie	Atchison, Topeka & Santa Fe Railroad.	No data.	405 lb.
Weber concrete tie.	Atchison, Topeka & Santa Fe Railroad.	No data.	467 lb.
F. R. White Mfg. Co., Suite 601, Evans Bldg. Washington, D. C.	Baltimore & Ohio, Sand Lick Branch, Monongah Division.	1 cement, 2 sand, 3 gravel.	1 000 lb.

(...ontinued.)

...ration of test or service.	Result.	Remarks.
141 days.	Used 50 ties in a joint track about 1919. Ties were very large (10 × 14 inches in section). The ties broke up badly and when the last one was removed the average life was 141 days.	Do not hold track in surface as well as wood tie.
3 years.	Used 50 ties under 85-lb. rail, main track, light traffic. Installed in 1922 and 1923. All were removed in 1925 due to being badly shattered by derailment.	...
12 years.	Used under 80-lb. rail and 23 were installed in May 1916. Subject to light traffic, main track service and light yard switching. On 10 September 1928 all were in service and in good condition.	...
1 year.	100 ties used under 90-lb. rail and installed in February 1926 on a high speed, heavy service, passenger and freight track. By 17 June 1927 two ties had been removed. Remaining 98 ties were all in service. By November 1927, all were removed due to failure of ties by cracking through the middle and having trouble to hold gage.	Unsatisfactory.
16 years.	Used 9 ties on main track. Installed on 18 October 1911. Prior to 15 December 1913, 8 had been removed to a side track. One tie was missing.	Will not hold track in surface as well as wood tie.
7 years.	Used 46 ties on main track, installed 15 February 1917. Last one removed 30 April 1923. Broke up badly under rails and elsewhere.	Did not hold track in surface as well as wood tie.
5 months.	Used 30 ties furnished by the Maryland Coal Co. 16 November 1915. Track on light fill. Used under 85-lb. rail. Traffic light. Began to crack soon after being put in. By April 1916, 6 ties had been removed due to cracking through. Eight others were also cracked to varying degrees. Majority of cracks were on high rail side.	Test was very unfavourable. Tie contains nearly 7 cubic feet of concrete.

TABLE II.

Detail result of canvass arranged alphabetically by name of manufacturer.

NAME AND MANUFACTURER.	*Used by.*	*Duration of test or service.*	*Result.*
American concrete tie. *Originally known as the « Dickey Tie ».*	Norfolk & Portsmouth Belt Line.	6 years.	Used under 85-lb. rail on yard track and heavy switching service. Installed 18 on 4 June 1919 and ties were in good condition on 6 October 1925. Should last indefinitely.
		2 years.	Installed 100 ties 18 September 1923. By 6 October 1925, 9 were broken due to not being built according to specification. Remaining 91 in good condition and giving good service. Used on heavy freight service exclusively.
		2 years.	Installed 20 ties 20 October 1923. 6 October 1925 all were in good condition and giving good service. Used on heavy freight service exclusively.
Bakers timeproof sleeper. *Concrete Railway Sleepers Co. Ltd., 2, Deans Yard, The Sanctuary, Westminster, S. W. I.*	Ceylon Government Railway.	Average 2 years.	Used 500 under 80-lb. and 88-lb. rail, few failures. Riding easy and no wear on rail. Mixed traffic.
Bates concrete tie	Elgin, Joliet and Eastern Railway.	17 years.	Used 62 ties under 85-lb. rail. Heavy freight service. Ties were installed May 1912 and on 29 June 1928 were still in good condition.
Buhrer concrete tie	Lake Erie & Western Railroad.	20 years.	Installed 5 ties in August 1903. By 5 August 1923 they were all in very bad condition. Removed 18 June 1924.
« Casey » concrete tie. *Concrete Tie Co., Pittsburgh.*	Pennsylvania Railroad (Central Region).	3 years.	Used 510 under 130-lb. rail on heavy freight service. Installed 1925 and are still in use 27 September 1928, except 46 ties which failed due to breaking.

« Brown »). Concrete Tie Co., Pittsburgh.	(Eastern Region).		and passenger track. Heavy service. In April and May 1928 upon examination 203 ties showed slight cracks, not serious. 39 ties had serious cracks, fractures or showed signs of crumbling or crushing.
Chamberlin concrete tie	Terminal Railroad Association of St. Louis.	5 years.	Used under 80-lb. rail, light switching yard service. 10 put down in 1920. Taken up in 1925 badly broken up.
Duke reinforced concrete tie	Atlanta & West Point Railroad. The Western Railway of Alabama. Georgia Railroad.	Several years.	Used 12 under 90-lb. rail, high speed, heavy freight and passenger service. Put in June 1927 main track. Good service.
Eastern Bengal Railway concrete tie .	Eastern Bengal Railway.	No data.	A few ties were used; no data regarding the result.
J. J. Finlayson, District Engineer.	Ceylon Government Railway.	Average over 5 years.	Used 1 600 under 80-lb. and 88-lb. rail. Few failures. Riding easy and no wear on rail. Mixed traffic.
Fukagawa type	Government Railways, Japan.	About 2 years.	Used 150 under 60-lb. rail. Low speed track. Put down in March 1927.
Green-Moore concrete sleeper, L. Green, Esq., c/o ***Lloyds*** *Bank, Ltd., Pall Mall, London.*	East Indian Railway.	8 years.	Used under 88 1/2-lb., 90-lb. and 100-lb. rail. Subject to heavy loads and high speed. Some removed due to breaking. Gave excellent running. Not used as standard.
Hanna cement tie	Atchison, Topeka and Santa Fe Railroad.	11 years.	All 8 ties used broke through under one or both rails.
Hatch tie. Morgan Park Company, Duluth.	Duluth & Iron Range Railroad.	5 1/2 years.	Used under 80-lb. rail on heavy freight service. Installed 11 in main line track July 1923 and on 12 October 1928, 7 were in good condition, but 4 showed considerable disintegration of the concrete. None have failed.
Ickes concrete tie. The American Concrete Tie Co. .	Kansas City Southern Railway.	Nearly 8 years.	Early part of 1921, 27 ties placed in main line track under 80-lb. rail. 17 failed in short time and were replaced in October 1922 on an industry spur. By 1 August 1924, 6 were cracked through the center, 2 near the bearing surface and 2 were cracked in other places. Light traffic.

TABLE II. *(Continued.)*

NAME AND MANUFACTURER.	Used by.	Duration of test or service.	Result.
Ickes concrete tie. *Chanute, Kansas.*	Atchison, Topeka and Santa Fe Railroad.	3 1/2 years.	Used 7 ties on passenger side track. All failed by breaking.
Kimball concrete tie	Pere Marquette Railway.	27 years.	Used 1 800 ties under 75-lb. and 90-lb. rail. Slow speed passenger service.
King foreign concrete tie	Long Island Railroad.	4 1/2 years.	Used 33 ties under 100-lb. rail. Slow speed exclusively passenger traffic. Installed in June 1924, track Cl. 1.
Maine Concrete Tie, Corrina, Maine . .	Bangor and Aroostook Railroad.	5 years.	Used under 85-lb. rail on high speed heavy passenger and freight service. 10 ties were installed on 11 December 1923. The ties were interlaced with cedar ties. On 30 August 1924 the cedar ties were removed and 59 additional concrete ties put in. On 30 May 1928 all were in service.
	Atchison, Topeka and Santa Fe Railroad.	6 1/2 years.	Used 21 ties in main track. Did not hold track in surface.
Marriott sleeper	London & North Eastern Railway.	9 years.	Used on slow line. Ties stood fairly well except those next to rail joint. Not successful on fast line.
McDonald concrete tie	Los Angeles Railway.	16 years.	Used under 87-lb. rail on high speed passenger service. In July 1911, 4 323 were put in service. By 11 July 1925, 40 removed due to installation of special work. Due to reconstruction of track, by 11 August 1927 only 736 remained. Replaced by creosoted pine ties.
Moore concrete tie . . . . *S. B. Moore.*	Southern Pacific Lines.	5 years.	In January 1917, 40 ties were installed. On 8 August 1922, 38 remained. All were removed in November 1922 due to poor bond between concrete and steel reinforcement and ineffectiveness of fastening.
M. R. N. C. C. reinforced concrete sleeper.	London, Midland and Scottish Railway, Northern Counties	Average 11 years.	Used 86 ties under 85-lb. rail. Mixed traffic. Slow and high speed service.

[illegible]			1914, 2 ties removed due to breaking. 1915, 3 ties removed (1 broke and 2 had broken screw spikes,due to relaying rail). 1918, 16 ties removed due to breaking. 1919, 1 tie removed due to breaking. On 8 August 1922, 26 remained, but should have been removed. Screw spikes not effective. By 16 October 1923, all were removed.
Riegler concrete tie	Pennsylvania Railroad (Central Region).	20 years.	Originally used under 85-lb. rail. In 1910 used under 100-lb. rail. On 31 october 1921 changed to 130-lb. rail. 15 were installed in May 1908 on track Cl. 1 through and suburban passenger service. In December 1914 placed in track Cl. 3 freight and through passenger service. 1926 and 1927, 7 were repaired due to crushing on one end. On 26 August 1927 all 15 ties were in service. Test closed 11 June 1928.
Ring type sleeper	London & North Eastern Railway.	Not 6 months.	Concrete broke and crushed. Exposed reinforcement.
Santa Fe concrete tie (Santa Fe Test, Topeka).	Atchison, Topeka & Santa Fe Railroad.	About 4 years.	Used 6 ties in lead in Topeka Yard. All failed by breaking.
Saxon concrete tie, Plastic Railroad Tie Co., Tecumseh, Oklahoma.	Atchison, Topeka & Santa Fe Railroad.	3 years.	Used 33 ties on main-tracks. Removed on account of breaking.
South Manchuria Railway	South Manchuria Railway.	Recently.	Used at engine sheds. No upheaval or destruction.
Southern Pacific concrete tie	Southern Pacific Lines.	1 1/2 to 12 years.	Used in light and heavy service on branch and main lines. Ties cracked.
Southern Pacific-Santa Fe concrete tie .	Southern Pacific, Santa Fe.	141 days.	Used for joint tracks. Broke up badly.
Stent's Patent (made in Delhi), D. H. Stent, c/o Messrs. Bird & Co., Calcutta.	Ceylon Government Railway.	Over 4 years.	Used 500 under 80-lb. and 88-lb. rail. Few failures. Riding easy and no wear on rail. Mixed traffic.
	London & North Eastern Railway.	Less than 1 year.	Used on low and high speed tracks. Freight and passenger service.
Taunton Division, reinforced concrete sleepers.	Great Western Railway.	From 2 to 11 years.	Used 196 ties under 80-lb. and 92-lb. rail on main and branch lines. Practically all were failures.

TABLE II. (Continued.)

NAME AND MANUFACTURER.	*Used by.*	*Duration of test or service.*	*Result.*
U. S. Indestructible tie	Detroit, Toledo & Ironton Railroad.	3 years.	50 used under 85-lb. rail, main track, light traffic. All removed in 1925 due to being badly shattered by derailment. Were installed in 1922-1923.
	Southern Pacific Lines.	12 years.	Used under 80-lb. rail and 23 were installed in May 1916. Subject to light main track service and switching. All still in service and good condition 10 September 1928.
		1 year.	Used under 90-lb. rail and 100 were installed in February 1926 on a high speed heavy service passenger and freight track. By 17 June 1927 two ties had been removed. Remaining 98 ties all in service. By November 1927 all were removed due to failure of ties by cracking through the middle and having trouble to hold the gage.
Waller & Reece concrete tie. . . .	Atchison, Topeka and Santa Fe Railroad.	16 years.	Used on main track until 1914, then on side track.
Weber concrete tie	Atchison, Topeka and Santa Fe Railroad.	7 years.	Used 46 ties on main track. Broke up badly.
F. R. White Mfg. Co., Suite 601, Evans Bldg., Washington, D. C.	Baltimore & Ohio Railroad, Sand Lick Branch, Monongah Division.	5 months.	Used under 85-lb. A. S. C. E. rail. Light freight traffic. Began to crack soon after being put down. Majority of cracks were on high rail side and entirely through the ties.
Yoke concrete block sleeper	London & North Eastern Railway.	12 years.	Used on branch and main lines. Concrete blocks none the worse for wear, but the tie bars corroded and a number were replaced.

B. – Concrete and reinforced concrete buildings.

Considerable progress has been made in the general use of reinforced concrete for building construction on railroads since the ninth Congress (Rome 1922). This increase in use of concrete for buildings is due largely to the general desire to secure buildings of more permanent construction, to reduce maintenance and to eliminate fire hazards. Improvements in materials and in methods of construction have played an important part in this increased use of concrete.

To secure data covering this subject, a canvass was made in the form of a questionnaire sent to various railroads throughout the territory covered by this report. Ninety-nine questionnaires were sent out and fifty-eight replies received. Of these fifty-eight, forty-two report use of concrete for building work. The above figures are divided geographically as follows :

Countries.	Canvassed.	Answered.	Use concrete.
Africa	6	2	1
Argentina	9	5	2
Australia	3	0	0
Brazil	3	1	1
Canada	2	2	1
Ceylon	1	1	0
Chili	3	0	0
China	4	1	1
Great Britain	11	8	6
India	11	4	3
Ireland	5	2	1
Japan	2	1	0
Malaysia	1	1	1
Mesopotamia	1	1	1
Salvador	1	0	0
United States	34	28	24
Uruguay	2	1	0

A summary of the canvass is given in table III, arranged alphabetically by countries. It is interesting to note increasing confidence in the use of reinforced concrete for building construction, as indicated in the following reports :

Asia, Mesopotamia.

Iraq Railways. — Concrete and reinforced concrete have been used in building construction for staff quarters, station buildings and a hospital. The buildings are mostly of one story, and steel was found unsuitable. Bricks were not used on account of expense and inferior quality available. Wood is scarce and does not withstand the climatic conditions. The construction generally adopted is the « Winget » block, made of one part cement, one part sand, and two parts stone. Mass concrete buildings have been constructed of one, three, six proportions. The lack of skilled workmen prevents the use of reinforced concrete to any great extent.

Argentina

The Central Argentine Railway. — This railroad has for many years employed reinforced concrete in the construction of water tanks, both circular and rectangular, the former ranging in capacity from 22 000 to 33 000 gallons, the latter from 35 000 to 44 000 gallons, but only recently has this form of construction been used for buidings. Figures 9 and 10 show a reinforced concrete locomotive running shed erected in 1928 at Villa Maria. Building is approximately 100 feet by 300 feet. Foundations were constructed of one part cement, two parts sand, and four parts granite. Columns, beams and roof slabs were constructed of one part cement, one and three-quarters parts sand, and three and one-half parts granite. Reinforced

Fig. 9. — Reinforced concrete locomotive running shed, Villa Maria, Argentina. Central Argentine Railway.

concrete structures have stood up very well and no failures are reported, despite the fact that since construction the above mentioned building has been struck by a cyclone. In general, however, brick is cheaper for most work.

Brazil.

The Leopoldina Railway. — Reinforced concrete construction was used for the Terminal Station Building and platform at Rio de Janeiro, completed in January 1928. This type of construction was used on account of its suitability in this climate, its fireproof qualities and negligible maintenance cost. Reinforced concrete piles were used of one part cement, two parts sand and two and one-half parts stone. Superstructure was constructed of one part cement, two parts sand, and four parts broken stone.

Canada.

Canadian National Railways. — Have used reinforced concrete for cattle and sheep barns at Point St. Charles, Tunnel Terminal Station at Montreal, coaling plants and grain elevators at various locations, and stores building at Toronto. Used in preference to steel to eliminate maintenance, and because of better fire resisting qualities, and greater economy where heavy floor loadings are required. Used in preference to brick in localities where concrete materials can be obtained locally and skilled labor is scarce; unskilled labor can be used on this class of work. Used in preference to wood to eliminate maintenance and reduce fire hazard.

China and Malaysia.

South Manchuria Railway. — All recently constructed large buildings are of reinforced concrete on account of greater permanency of construction and reduced maintenance costs. First cost is higher

Fig. 10. — Reinforced concrete running shed, Villa Maria, Argentina. Central Argentine Railway.

than wooden construction, but is cheaper than stone or brick; are also more resistant to earthquakes and more weather tight and fire resistant than wood.

Federated Malay States Railway. — Only one or two buildings of a minor character have been constructed of reinforced concrete, the important buildings being constructed of steel frame.

Great Britain.

Cheshire Lines Committee. — Cheshire Lines Committee have used precast concrete block construction largely for platelayer's cabins, shunter's huts, etc., on various parts of the system in preference to wood, on account of reduced maintenance costs, and in preference to brick, on account of lower first cost. Reinforced concrete is used generally for floor construction in offices and warehouses.

Great Western Railway. — In 1911, a reinforced concrete skeleton goods depot was erected at South Lambeth, and this building has proven so satisfactory that the railway company in 1928 constructed another adjacent to it of somewhat similar design. The new goods depot is approximately 350 feet by 50 feet, the general construction being indicated on figures 11 and 12. The Great Western Railway reports that reinforced concrete is a most useful material for this class of building and is preferable to steel frame.

London & North Eastern Railway. — The London & North Eastern Railway considers reinforced concrete suitable for building construction on account of durability, low maintenance cost, fire resisting properties, better distribution of loads on foundations and for marine

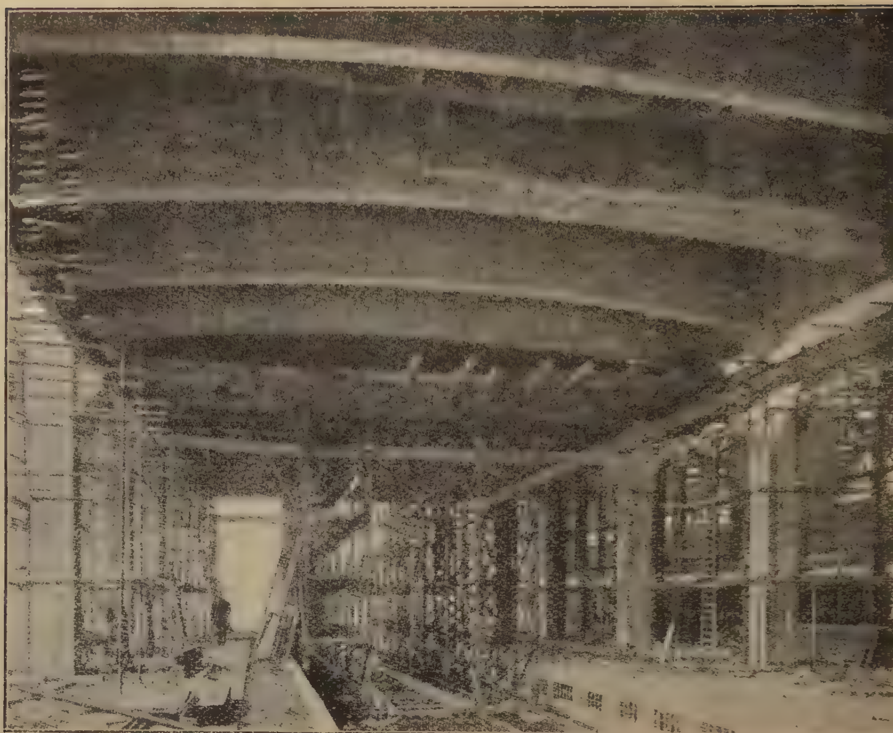

Fig. 11. — Goods depot at South Lambeth, Great Western Railway, Great Britain.

Undersides of main beams, showing also staging in position.

Fig. 12. — Goods depot at South Lambeth, Great Western Railway, Great Britain.

Basement view under platform.

work subject to destruction by marine worms. Reinforced concrete has been used for warehouses, grain stores, water tanks, silos and coal chutes and has been found very satisfactory.

Metropolitan Railway. — Reinforced concrete was used for the construction of the Head Offices at Baker Street, London, erected about 15 years ago. The design was based on the Coignet system. This building has been quite satisfactory. No recent installations are reported. Do not generally advocate the use of reinforced concrete for the whole of a building on account of slowness of the work, extensive amount of shuttering required, and difficulty and cost of any subsequent alterations. Present practice is to use reinforced concrete for floors, staircases and flat roofs, and it is considered advantageous for this work.

India.

East Indian Railway. — A few concrete buildings have been erected, of which two were engine sheds. The use of reinforced concrete as opposed to brick and steel was not found economical except during the period immediately following the war.

Great Indian Peninsula Railway. — Reinforced concrete is recommended for floors and platforms in station buildings and goods sheds, generally of precast construction. Can be taken up and re-erected on other sites without loss. Chief saving in use of this type of platform is due to the fact that no foundation is required. For ordinary buildings, masonry is usually cheaper.

The Madras and Southern Mahratta Railway. — Only one bungalow has been built and the type has not been repeated, as local brick was considered more suitable.

Ireland.

London, Midland & Scottish Railway, Northern Counties Committee. — Reinforced concrete construction is recommended for building construction. The chief point in adopting reinforced concrete is to cut down maintenance expenditure. Reasonable excess of first cost over timber or steel construction is permissible. It can be used for any kind of building which is expected to have a reasonable length of life and is recommended on account of ultimate economy and for fire-proofing consideration. A goods shed was constructed in 1916 at Doagh of precast reinforced concrete and this type of construction is considered very suitable for railways. It enables the units to be cast by a small skilled staff at headquarters and erected on the site with a minimum of skilled labor in a relatively short time.

United States.

Reinforced concrete construction has been in quite general use on railroads in the United States for the past ten to fifteen years for coaling stations, warehouses, oil houses, pump houses, and for miscellaneous small buildings such as train control houses, block stations, watchman's huts, scale houses, shelter houses, and for foundations and floor and roof construction in all classes of buildings. In many instances, engine houses, shops, freight houses, grain elevators and office buildings have been constructed entirely of reinforced concrete. Permanence, reduced maintenance, and fire resistance have been the main reasons for its use. In general, the first cost is somewhat higher at the present time than steel frame and brick, though, of course, there are cases where reinforced construction is cheaper. Objection to

Fig. 13. — « Massey » block station, U. S. A.

use of reinforced concrete construction is difficulty and high cost of making alterations, but this objection is not serious where alterations are not likely to be required, or if ample provision is made for future needs.. Detail reports from various railroads in the United States are given in table III.

An interesting development in reinforced concrete building construction on railroads in the United States is the use of pre-cast construction for small buildings, such as watchman's huts, oil houses, telegraph booths, block stations, train control stations, pump houses and scale houses. Figures 13, 14 and 15 illustrate typical buildings of this style as constructed by the Massey Concrete Products Company, of Chicago, Ill. Upwards of one thousand of these buildings have been built within the past ten years on railroads in the United States, including the Baltimore and Ohio, Delaware, Lackawanna and Western, Erie, New York, New Haven and Hartford, New York Central Lines, and the Pennsylvania System. These buildings are poured complete as one unit, including floors, walls and roof. Either steel or wood sash and doors are used. Construction is practically all done at the factory and building transported to the site on flat cars. Walls, floor and roof are three to four inches thick, reinforced to take care of stresses due to handling and erection. Concrete mix is one part cement, one and one-half parts sand, and three parts stone, rubbed to a smooth finish inside and outside.

Detail reports received from many rail-

Fig. 14. — « Massey » pump house, U. S. A.

Fig. 15. — « Massey » shelter house, U. S. A.

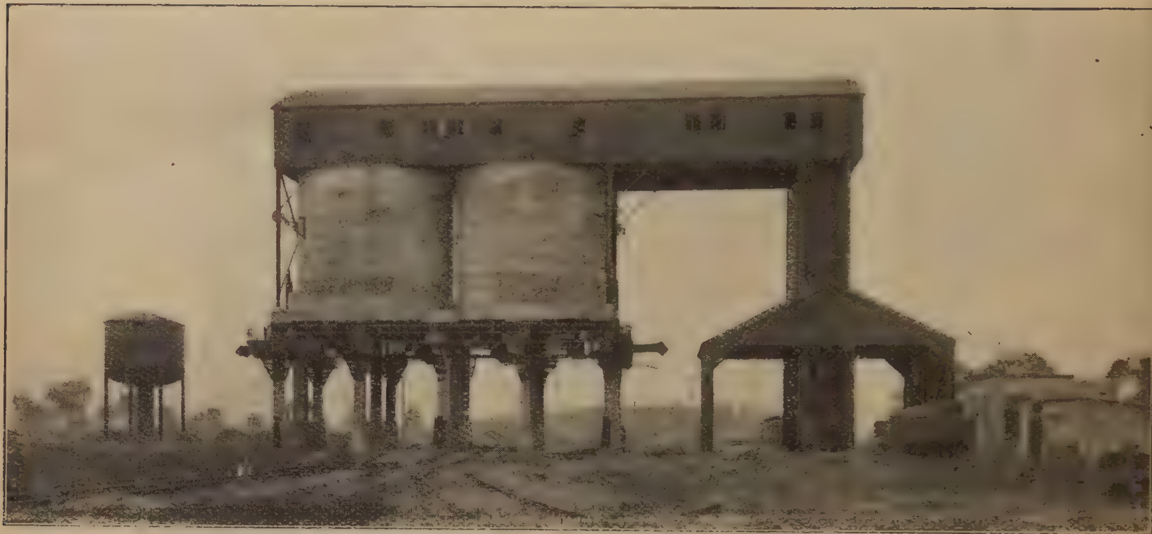

Fig. 16. — Coaling station, Selkirk, New York, U. S. A.
New York Central Railroad.

Fig. 17. — Engine house and fan house, Selkirk, U. S. A.
New York Central Railroad.

roads in the United States cannot be quoted due to lack of space. However, a summary is given in table III, and typical reinforced concrete constructions recently made are listed below :

Bangor & Aroostook Railroad. — A few years ago the Bangor & Aroostook Railroad built three reinforced concrete engine houses. Reinforced concrete was chosen for these buildings so as to provide a fireproof building and one that could be maintained at small cost. These buildings have been in service from two to five years. There have been no failures. Concrete or reinforced concrete is well suited for all classes of railroad buildings, such as engine houses, warehouses, etc. where the appearance of the buildings is not concerned, as concrete or reinforced concrete does not seem to lend itself very well to architectural effects.

Central of Georgia Railway. — The Central of Georgia Railway built a round house two years ago at Savannah, Georgia, and five years ago constructed an oil house at Columbus, Georgia. Concrete and reinforced concrete were used chiefly for the reduction of fire hazard. No failures have occurred. The use of concrete is advocated for buildings where fire hazard is of prime importance and when reduction in maintenance will offset increased initial cost.

Chicago, Indianapolis & Louisville Railway. — About four and one-half years ago, the Chicago, Indianapolis & Louisville Railway built a reinforced concrete freight house at Indianapolis. Reinforced concrete was used in preference to steel, brick or wood, because the competitive designs showed this type of construction most economical for the particular layout in question and the building code required fire-proof construction. Reinforced concrete is advocated for buildings, but plain concrete is recommended only for unimportant underground footings or where the concrete is protected from temperature extremes and is only lightly stressed. There have been no failures of reinforced concrete.

Delaware, Lackawanna & Western Railroad. — Concrete and reinforced concrete have been used by the Delaware, Lackawanna & Western Railroad in construction of signal towers, stations, pier sheds, locomotive shops, a coal breaker and a firing-up house. A nine story warehouse and freight terminal at Jersey City is now in process of construction (fig. 19). The pier sheds referred to above, while not entirely of reinforced concrete, have reinforced concrete walls and floors on structural steel members. The locomotive shops at Scranton have been in service since 1908. There have been no failures. Reinforced concrete was used for fireproof quality, elimination of maintenance cost, and permanence of construction. Reinforced concrete buildings are advocated for most purposes, particularly where fire hazards occur.

Elgin, Joliet and Eastern Railway. — The Elgin, Joliet and Eastern Railway Company built coaling stations in 1923 and 1925, respectively. Concrete and reinforced concrete were used in preference to steel, brick or wood, due to economy, durability, resistance to fire, and general appearance. There have been no failures. Concrete or reinforced concrete are recommended for practically all kinds of railroad work. In case buildings are to be heated, provision should

Fig. 18. — « Central » passenger station, Buffalo, New York, U. S. A.
New York Central Railroad.

be made for proper insulation. For coaling stations, no insulation is necessary.

Illinois Central System. — At present, the Illinois Central is constructing a large reinforced concrete grain elevator. Concrete and reinforced concrete have also been used for foundations, footings, floors on fill, sub-floors and reinforced floor and roof slabs used in conjunction with steel columns and girders for all classes of railroad buildings, and in one or two instances the entire structural portion where the design has been adaptable to use of reinforced concrete. Because of greater adaptability and durability for the particular purposes used, because of its fire-resisting properties and because of the necessity to comply with local fire ordinances, concrete or reinforced concrete was used in preference to steel, brick or wood. Concrete has been used for over twenty years and there have been no failures. Where buildings are of regular proportions allowing for the re-use of forms and also where the loading does not require columns and beams of too large dimensions, concrete or reinforced concrete is advocated for all kinds of buildings where its use is considered satisfactory as compared to other kinds of materials.

New York Central Lines. — Reinforced concrete has been used for building construction for the past fifteen or twenty years. Use of this material for the whole of a building has not been the general practice, due primarily to the fact that combinations of steel frame and brick with reinforced concrete floor slabs have been more economical. Where additional fire resistance is required, the steel is encased in concrete. In some cases reinforced concrete has been used in combination with timber roof construction for reasons of economy and general serviceability. The objections to construction of complete structures of reinforced concrete have been, in general, high cost, additional weight requiring more expensive foundations, and the difficulty and cost of alterations. It has, however, been quite general practice to construct certain permanent structures entirely or reinforced concrete, such as coaling stations, warehouses, pump houses, store houses, and in a few cases, two and three story office buildings. A typical coaling station as constructed on the New York Central at Selkirk, N. Y., is indicated on figure 16. A typical combination of reinforced concrete, steel frame and timber construction is indicated on figure 17, showing engine house and fan house at Selkirk, N. Y. Figure 18, shows a combination of steel frame with reinforced concrete slab used in the new « Central » passenger station at Buffalo, N. Y. These photographs indicate typical construction which involves the use of reinforced concrete to a more or less degree and which have been found economical and serviceable. Considerable study has been given to securing concrete of permanence and durability by using the best materials, by using care in the grading of sand and stone, control of water-cement ratio and field regulation of the mix.

Norfolk & Western Railway. — The Norfolk and Western Railway Company has used concrete and reinforced concrete for coaling stations, office buildings, store houses, sand storage houses, oil houses, upholstering shops and for other purposes. Concrete and reinforced concrete were used in preference to steel many years ago in construction of coaling plants, for the reason that concrete

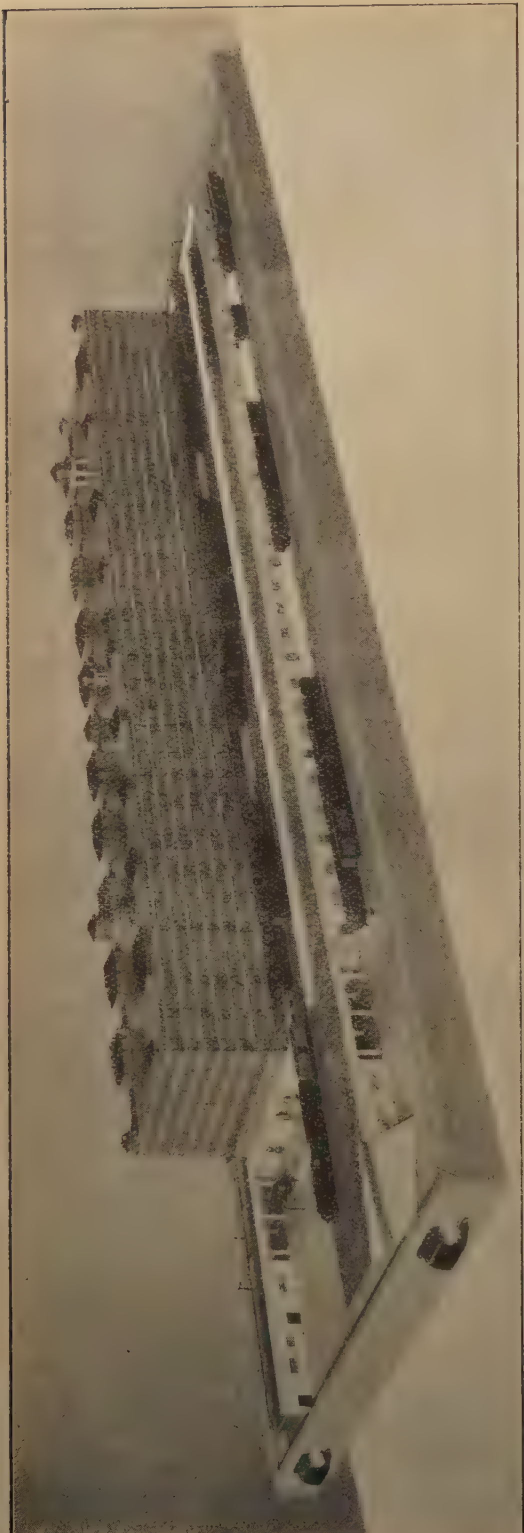

Fig. 19. — Model of warehouse and freight terminal, Jersey City, N. J., U. S. A. Delaware, Lackawanna & Western Railroad.

construction was regarded as being more fireproof and cheaper to maintain. The reinforcing steel, also, did not corrode as rapidly as the exposed structural steel. Reinforced concrete buildings and combinations of reinforced concrete and brick buildings were adopted principally on account of being more fireproof and also with the idea of reducing maintenance. No failures are reported. In a number of cases, however, during a period of exposure of twenty years, concrete protection has been forced off of certain reinforcing bars in coaling stations due to smoke and gases from locomotives. Repairs have been made and protection to the steel bars replaced by using « Gunite »; or where the defects were small, by cleaning and pointing up with cement mortar. Regarding damage by fire, in one case, on a reinforced concrete coaling station, fire from spontaneous combustion occurred in the coal storage pocket. This did not damage any of the side walls of the main pocket. Thin slabs on cinder fill, used for hoppers, were damaged in areas directly adjacent to the fire. Reinforced concrete buildings are advocated for coaling stations in particular and also for warehouses, sand houses, and oil houses. Conservative designs should be used and all thin walls avoided. Concrete is also recommended in combination with brick work for office buildings and other types of railway structures.

The Pennsylvania Railroad. — The Pennsylvania Railroad has used concrete or reinforced concrete for engine houses, store houses, coaling stations, oil houses, produce facilities, interlocking cabins, passenger stations, and miscellaneous structures for about eighteen years. Due to facility of construction, fireproof qualities, quicker delivery of materials, lower

first costs and less maintenance, concrete or reinforced concrete has been used in preference to steel, brick or wood. One failure occurred. It was a flat slab concrete building. The columns set, but the slab did not. Minor conflagrations have been withstood by concrete and reinforced concrete. Where buildings are of a permanent nature, where fireproof construction is desirable, such as oil houses, interlocking towers, coaling stations, etc., and where resistance to corrosion makes exposed steel work undesirable, concrete or reinforced concrete is advocated.

Pere Marquette Railway.— At the present time, the Pere Marquette Railway Company is constructing a reinforced concrete cold storage warehouse 60×160 feet at Grand Rapids, Michigan. This type of construction is also used for store houses, oil houses, coaling stations and power houses, because it has less fire hazard and gives stronger construction for the same cost, than steel or brick. The oldest building has been in service for six years. There have been no failures. Concrete and reinforced concrete is recommended for buildings that are permanent and which require strong floors and heavy construction.

Southern Pacific Lines. — The Southern Pacific Lines have constructed shop buildings, freight stations and grain elevators, using concrete and reinforced concrete. This type of construction was used because of its permanence. There have been no failures.

SUMMARY AND CONCLUSIONS.

The reports indicate a growing use of concrete and reinforced concrete for general building construction. Many buildings have been constructed entirely of concrete and have given excellent service. The cost of such buildings, however, has often been found to be greater than combinations of steel frame and concrete or brick. Nevertheless, the value of concrete and reinforced concrete for floors and platform construction and as a fire resisting material is universally recognized. Some failures are reported, but these are in general due to improper design, improper materials, or poor workmanship, and it is noted that in the more recent installations these features are being given more careful consideration. Dense concrete, secured by control of water-cement ratio and grading and regulation of the mix, is of prime importance and it is generally felt that greater strength, permanence and serviceability can be obtained along these lines. With more attention given to these fundamentals and with increasing knowledge of their value will come added confidence in concrete and reinforced concrete construction.

TABLE III.

Concrete and reinforced concrete buildings.
Result of canvass arranged alphabetically by geographical sub-division

COUNTRY AND RAILROAD.	*Duration of service.*	*Type of building.*	*Remarks.*
Argentina.			
Central Argentine Railway	1 year.	Water tanks, engine shed, inspection pits, piles.	Used due to its resistance to corrosion, low maintenance and heat resisting properties. No failures. Advocate armoured concrete for engine sheds, water tanks and culverts of small span.
Brazil.			
The Leopoldina Railway	2 years.	Terminal station building and platforms.	Reinforced concrete was used to economize time in construction, fireproof qualities and negligible maintenance cost. Advocate use for this kind of building. No failures.
Canada.			
Canadian National Railways	10 years.	Cattle and sheep barns, tunnel terminal station, coaling plants, stores building, foundation walls of freight sheds, grain elevators.	Eliminates maintenance, better fire resisting qualities, more economical in construction where heavy floor loadings required. Localities where materials can be obtained locally and skilled labor is scarce, unskilled labor can be used. Reinforced concrete is advocated in buildings such as storehouses, warehouses, coaling plants, etc., where heavy live floor loadings and fireproof construction is necessary. Also office buildings up to a certain height. Plain concrete in foundations for stations, engine houses, machine shops, section houses and generally all buildings not of a portable type in localities where skilled labor and other suitable types of material are hard to obtain. No failures.
China.			
South Manchuria Railway	No data.	Engine sheds, passenger car sheds, warehouses, offices.	Due to fire resistance, water tightness and ease to get materials for reinforced concrete, it is used in almost all large buildings. They are earthquake tight and of long duration. Cheaper than stone or brick.

Great Britain.			
Cheshire Lines Committee	6 years.	Platelayers' cabins, Shunters' huts, footbridges over railway.	Concrete blocks were used for various cabins. Cheaper to erect than brick. Economy also shown by manufacturing blocks at own works. Reinforced concrete used for footbridges because it was cheaper than brick abutments and steel girders. Maintenance cost reduced to a minimum. No failures. Advocate concrete for floors in office and warehouse buildings and for light bridges not carrying railway traffic.
Great Western Railway	29 years.	Principally warehouses.	Use concrete mainly on grounds of economy. No actual failures but where occasional faults developed, they were due to unsuitable material. Ferro-concrete is a most useful material for building warehouses and preferable to steel framing for this class of work.
London & North Eastern Railway . .	21 years.	Warehouses and floors, grain stores, water tanks, coal chutes, sylos, jetties.	Used due to low maintenance costs and durability and fire resisting properties. Also better distribution of load on bad foundation. No failures. Action of buildings against salt water, satisfactory. Advocate use of concrete if economical and where building will not be altered or taken down.
Metropolitan Railway	About 15 years.	Office building, girdering and platform, footbridge, staircases, flat roofs and floors.	Used due to economy. Have had no failures. The buildings are quite satisfactory regarding weather but have not been tested by fire. Do not advocate reinforced concrete for the whole of a building, but do advocate it for floors, staircases and flat roofs.
The Underground Electric Railways of London, Ltd.	About 8 years (footbridges).	Footbridges, covering over lift shafts, booking hall floors, staircases, platforms and roofs to signal cabins.	Used due to strength, ease of maintenance and fireproof qualities. No failures. Do not advocate its use for general building construction.
India.			
East Indian Railway	No data.	Engine shed.	A few concrete buildings were erected, the largest of which are two engine sheds. Not as economical as brick and steel, excepting during the period immediately following the war.

TABLE III. *(Continued.)*

COUNTRY AND RAILROAD.	*Duration of service.*	*Type of building.*	*Remarks.*
Great Indian Peninsula Railway	About 3 years (platform).	Floors, platforms.	More economic. No failures. Advocate reinforced concrete for platforms and floors.
The Madras and Southern Mahratta Railway.	No data.	Bungalow.	Only built one bungalow and type has not been repeated as local brick was more suitable.
Ireland.			
London, Midland & Scottish Railway (Northern Countries Committee).	About 15 years.	Goods sheds and minor sheds.	Used due to economy and fireproof qualities. Maintenance of timber buildings at outstanding stations in Ireland is expensive. There have been no failures. Reinforced concrete is advocated chiefly to cut down maintenance expenditure. Can be used for any kind of building which is expected to have a reasonable length of life. Use of pre-cast units is very suitable for railways. Units can be cast by a small skilled staff at headquarters and be erected on site by minimum skilled labor in short time.
Malaysia.			
Federated Malay States Railways	No data.	Minor buildings.	No data.
Mesopotamia.			
Iraq Railways	7 years.	Staff quarters, station buildings, and hospital.	Used because most of buildings are only one story. Less expensive than bricks (especially after the war). Wood is scarce and does not withstand the climatic conditions. There were some failures, due to chemical action through impure materials having been used. Advocate use of concrete in hot climates for buildings only when cost of bricks or their quality make them uneconomical. Excellent for bridge work. Due to lack of skilled workmen, concrete cannot be used to much extent.
United States.			
Atlanta & West Point Railroad, Western Railway of Alabama, Georgia Railroad.	15 years.	Freight depot and warehouse.	No data.

		tions & pump houses.	economical; better adapted to some forms of construction and has better fireproofing qualities than steel or wood. No failures. Advocate use, where adaptable.
Bangor & Aroostook Railroad . . .	From 2 to 5 years.	Engine house.	Used due to its fireproofing qualities and small cost of maintenance. No failures. Advocate use for all railroad buildings such as engine houses, warehouses, etc., where appearance of building is not considered because it does not lend itself very well to architectural effects.
Bessemer & Lake Erie Railroad . .	19 years.	Round house, pattern shop, storehouse, dope house.	Used due to being fireproof and stable. No failures. Advocate such buildings for storehouses where heavy loads are carried and there is fire hazard.
Central of Georgia Railway	From 2 to 8 years.	Freight station, engine house, coaling station, oil house.	Used chiefly for reduction of fire hazard. No failures. Advocate use of concrete for building where fire hazard is of prime importance and when reduction in maintenance will offset increased initial cost.
Chicago, Indianapolis and Louisville Railway.	4 1/2 years.	Freight house. Footings and floors (passenger depot).	Used because it was more economical for particular layout and was fireproof. No failures. Advocate use of reinforced concrete under almost any condition, but not plain concrete.
The Delaware, Lackawanna and Western Railroad.	20 years.	Signal towers, stations, pier shed, locomotive shop, coal breaker and firing up house. Warehouse and freight terminal.	Reinforced concrete used due to its fireproof quality, elimination of maintenance cost and permanence of construction. No failures. Advocate use of reinforced concrete buildings for most purposes, particularly where fire hazards occur.
The Duluth and Iron Range Railroad.	From 12 to 22 years.	Oil house. Pattern storage. Balcony in machine shop. Round house. Paint shop roof. Warehouse.	Used due to great fire resistance. Regarding fish warehouse, could be cleaned by flushing with less injury. No failures. Recommend such buildings where fires are apt to be costly and wherever other cases justify the extra cost.

TABLE III. *(Continued.)*

COUNTRY AND RAILROAD.	*Duration of service.*	*Type of building.*	*Remarks.*
Elgin, Joliet and Eastern Railway . .	From 3 to 18 years.	Roundhouse, tool house, coaling station.	Concrete used due to its economy, durability, resistance to fire and general appearance. No failures. Advocate use of such construction. Can be used in all kinds of railroad buildings.
The Hocking Valley Railway . . .	From 10 to 15 years.	Frame for yard office. Buildings of reinforced concrete construction. Sand and oil house, coal bunks.	Used due to its fireproof qualities, permanence and maintenance. No failures. Advocate its use for sand houses, oil houses and coal bunks.
Illinois Central System	20 years.	Foundations, footings, floors, roof slabs, grain elevator.	Used because of greater adaptability and durability for the particular purposes at hand and fire-resisting properties. No failures. Advocate use for all kinds of buildings where satisfactory to other kinds of materials — also where buildings are of regular proportions, allowing for the re-use of forms.
The Kansas City Southern Railway .	13 years.	Grain elevator.	Used reinforced concrete because it was more economical. No failures, but had some trouble with bars due to being placed too close to the surface, which permitted bars to rust and break concrete surface. Fire did little damage. Recommend concrete and reinforced concrete for railroad buildings when of permanent nature.
Lehigh and New England Railroad .	10 to 12 years.	Telephone booths, passenger shelter.	Used due to less maintenance, and small concrete buildings were portable when necessary to relocate them. No failures. See no advantage in concrete buildings over brick.

Lehigh Valley Railroad	No data.	Coaling stations, round houses, warehouses.	Failures were due to gas and steam from engines. Withstood action from salt water. Advocate its use for railroad structures, such as platforms, grain elevators, storage bins, warehouses, foundations.
New York Central Railroad	15 to 20 years.	Coaling stations, warehouses, pump houses, store houses, office buildings.	Used due to economy, general serviceability, and is recommended for permanent structures.
Norfolk and Western Railway	From 2 to 21 years.	Coaling station, office building, store house, sand storage house, oil house, upholstering shop.	Used because more fireproof, maintenance low, and no corrosion. No failures. No serious damage due to fire. Advocate use of reinforced concrete structures.
Pennsylvania Railroad	17 to 18 years.	Engine houses, store houses, coaling stations, oil houses, produce facilities, interlocking cabins, passenger stations.	Used on account of facility of construction, often lower first cost, less maintenance, fireproof qualities, and quicker delivery. Advocate use of concrete for permanent structures, being fireproof and not allowing corrosion of steel.
Pere Marquette Railway	6 years.	Store house, oil house, coaling station, power house.	Used due to less fire hazard and stronger construction for same cost. No failures. Recommended for any building that will be permanent and requires strong floors and heavy construction.
Reading Company	11 to 16 years.	Store and oil houses, warehouse, engine house.	Used due to permanency and fireproofness and economy. No failures. Advocate the use of reinforced concrete for store houses, oil houses and warehouses, but not for engine houses.
Richmond, Fredericksburg and Potomac Railroad	16 years.	Pump house.	Used due to its fireproof and permanent construction. No failures. Advocate such buildings for permanent structures.

TABLE III. *(Continued.)*

COUNTRY AND RAILROAD.	*Duration of service.*	*Type of building.*	*Remarks.*
Southern Pacific Lines	3 to 18 years.	Shop buildings, freight stations, grain elevators, causeway.	Used due to its permanence. No failures. After 18 years, the causeway, subject to salt water, shows no signs of deterioration.
Southern Railway System	17 years.	Structural frame and slab of round house. Structure, floor & roof slabs of office buildings.	Used because it is cheaper, and in the case of round houses the steel is protected against gases. No failures. Advocate the use of concrete and reinforced concrete where it proves economical and practicable.
Terminal Railroad Association of St. Louis.	16 years.	Passenger station.	Used due to being fireproof and cheaper. No failures. Advocate use of reinforced concrete for buildings as a skeleton when it can be protected from the weather, because it is cheaper than structural steel when latter must be fireproofed.
The Atchison, Topeka and Santa Fe Railroad.	20 years.	Engine house, depots, signal towers, office buildings.	Used due to its fire protection and reduced cost of maintenance. Had failures in engine house due to excessive gases. No damage from minor quakes in California. Advocate use of concrete in any type of building where suitable framing is used and spans require heavy girders.

[625 .143]

REPORT No. 1

(**America**)

ON THE QUESTION OF RESISTANCE OF RAILS AGAINST BREAKAGE AND TO WEAR; RAIL JOINTS (SUBJECT II FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRES ASSOCIATION) (1),

By R. B. ABBOTT,

ASSISTANT GENERAL SUPERINTENDENT, READING COMPANY.

Figs. 1 to 3, pp. 485 and 487.

Impelled solely by a desire to amplify where justifiable and without wasting time in profitless duplication of the excellent work and conclusions of our predecessors who have handled the important subjects covered herein, we therefore broadcasted a questionnaire in as abbreviated a form as possible with the hope of securing the benefit of any new developments or thoughts that have been occasioned by actual practice and use since the report submitted by Mr. Cushing to the London Congress in 1925 (1).

A. — *First causes of rail breakage; measures taken to reduce the number of breakages, both as regards the way rails are used and the conditions of inspection.*

Rail breakage may be due to a single cause or to a combination of circumstances. Among the direct causes may be listed the following :

Transverse fissure.

Shattering cracks due to rolling directly from the ingot and with too few passes through the rolls.

Engines badly counterbalanced.

Seams in the rail base.

Rail section too small for load imposed.

Poorly maintained track.

Mechanical damage by defective car or locomotive equipment.

Excessive lateral wear on curves.

Excessive strain set up by the straightening methods at the mills.

Reduction of section due to corrosion or oxidation.

For main tracks and other heavy duty tracks, the number of ties used should be

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(1) This question runs as follows :

« *A*) First causes of rail breakage ; measures taken to reduce the number of breakages, both as regards the way rails are used and the conditions of inspection.

» *B*) Quality of metal used for rails to give normal wear. Conditions governing manufacture and inspection.

Rails : profile and quality, length, weight, and cross section of the rails.

» *C*) Rail joints. The most economical and efficient design. »

(2) See *Bulletin of the Railway Congress*, October 1924 number, page 677.

the maximum possible and still leave room necessary for thorough tamping. A track is no stronger than its supports and it is the combined surface area of the bottoms of the ties, within a spread of about fourteen inches on each side of each rail, that holds up the track and keeps the vertical deflection of the rail within reasonable limits.

A number of the railroads in America assign crossties on the basis of eighteen to a thirty-three foot rail but most of the heavy traffic roads use twenty to a thirty-three foot rail and it is our opinion that the larger number is entirely justified.

Inspection of rails in track should be such as to insure proper maintenance of joints, line and surface, correct super-elevation, proper rate of run-off at beginning and end of curves, and all other conditions that would have any effect on the life of rail in track.

Qualified track walkers should walk over and inspect all main track mileage once a day and as much oftener as special circumstances may warrant.

Where practicable to do so, rails should be lifted or slid off of cars and not dropped on solid, irregular surfaces.

Mechanical means for the loading, unloading and laying of rails should be utilized wherever available or procurable, and there are many efficient machines on the market.

In the handling of heavy rails, frogs and switches, labor saving machines are not only labor saving but are also labor conserving as they eliminate or greatly reduce the danger of rupture and other serious injuries to the men employed.

« A » rails should be segregated and used only in tracks carrying relatively light traffic or tonnage moving at low speed.

B. — *Quality of metal used for rails to give normal wear. Conditions governing manufacture and inspection.*
Rails : profile and quality, length, weight, and cross section of the rails.

Most of the railroads reporting employ the current Specifications of the American Railway Engineering Association for Open Hearth Carbon Steel Rail.

Experimentation is now going on with head-treated rails and rails having abnormal proportions of manganese and other hardening elements.

Some railroads take care of their own inspection while others employ outside forces.

Heaviest rail used in America is the 136-lb. Lehigh Valley section. However, 130-lb. sections predominate on heavy traffic lines.

There is a strong tendency among the railroads generally to adopt American Railway Engineering Association standard sections or modifications of them. However, some of the railroads have their own series of sections and may retain them indefinitely.

Most roads are now using rails thirty-nine feet long. Some roads, however, in South and Central America use rails forty feet long.

To eliminate or reduce the number of track joints within the limits of road crossings and station grounds, rails sixty-six feet long are used by several roads. This results not only in economy but also in better riding track.

C. — *Rail joints. The most economical and efficient design.*

Study of the answers to the questionnaire (see Appendix) shows that, with single exception of the Thomson Head-Free Rail and Head-Free Continuous Angle Bars, there have been no outstand-

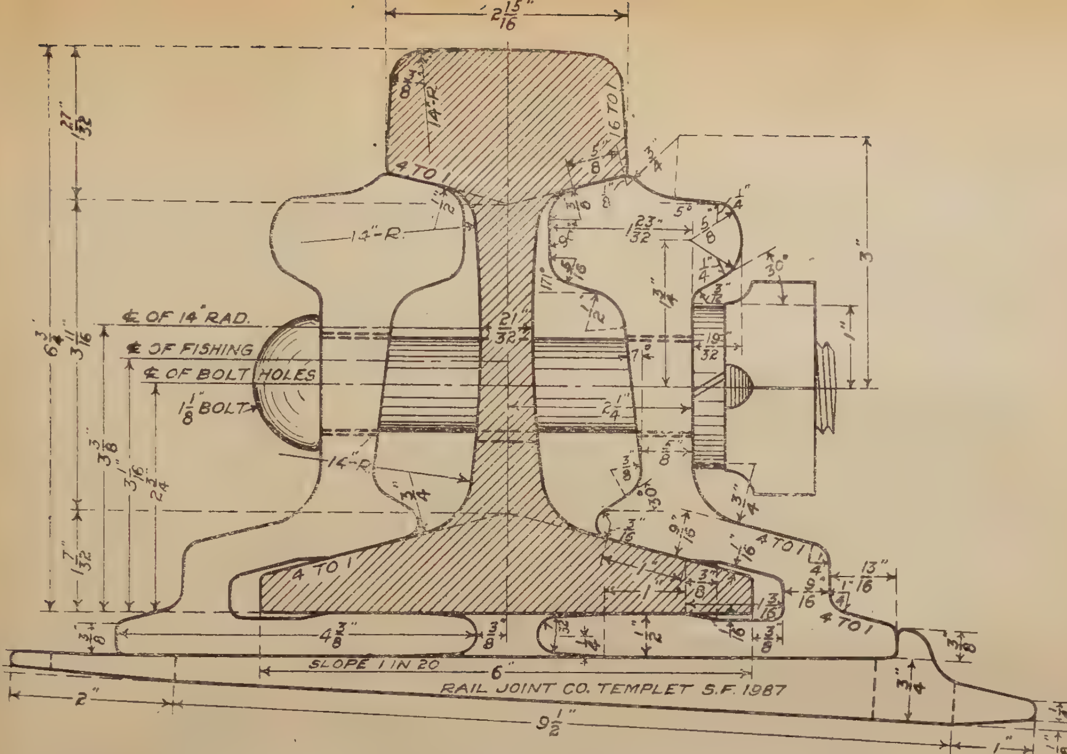

Fig. 1. — R. E. rail and joint continuous head-support type with abrasion plate.

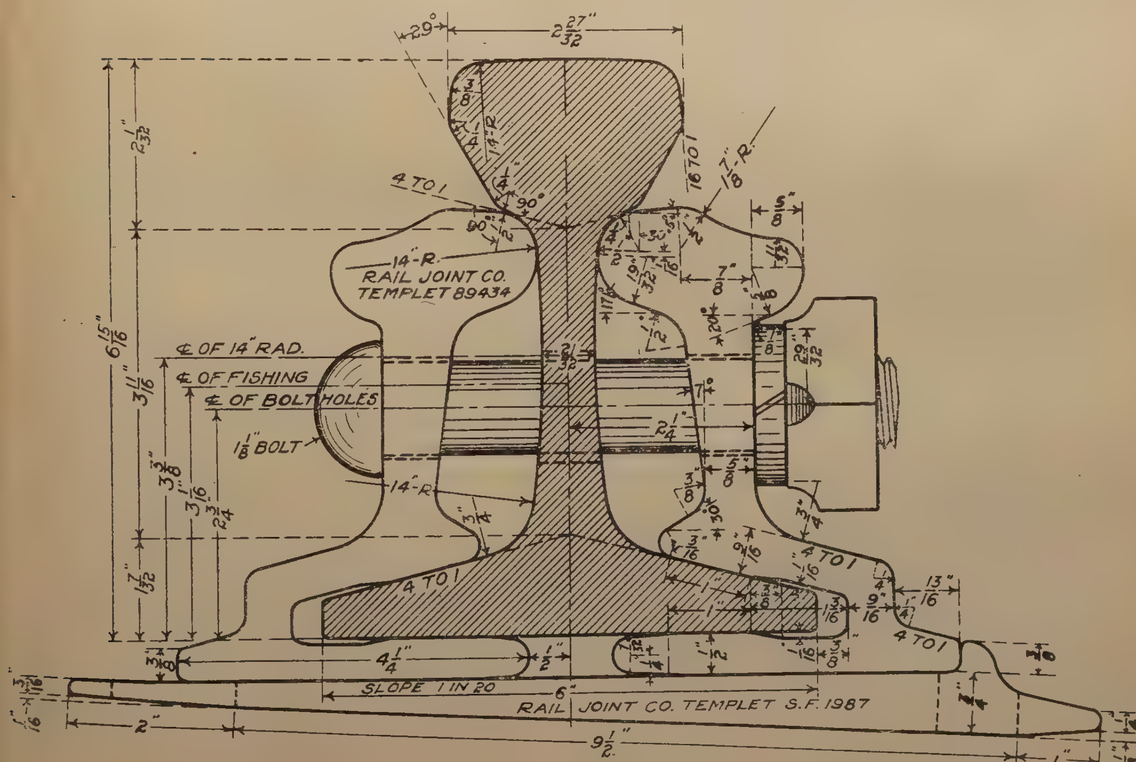

Fig. 2. — 130 H. F. B. rail and joint continuous head-free type with abrasion plate.

Note the abrasion plate under each joint which greatly retards mechanical damage to ties under maximum wheel loads.

ing changes or improvements in rail and angle bar design since Mr. Cushing's report referred to in opening paragraph.

Therefore, this report will deal principally with the development and performance of the head-free angle bars and head-free rail as used on the heavy duty tracks of Reading Company.

The angle bar is named first because the rail section was really a complement of the angle bar and could not have been employed unless the latter had first demonstrated its soundness in theory and efficiency in actual service.

Reading Company is a railroad having 1 796 miles of main tracks and carrying very heavy traffic and maximum wheel loads. Therefore it is fair to assume that any joint and rail section that performs satisfactorily on Reading Company tracks would be equally successful under any and all conditions imposed on other railroads of heavy traffic density.

Prior to the development of the head-free angle bar, it had always been considered an essential of design that clearance of about 3/16 inch should be provided at top and bottom between sides of angle bar and the web of the rail. This clearance was deemed essential to provide take-up for wear.

The top of the angle bar pressed against the under side of rail head and this was also considered an essential of design.

However, the head-free angle bar does not give head support to the rail except in the area comprised by the fillet where the head joints the web. Necessary clearance for take-up is afforded at bottom of bar. This take-up at the bottom of bar together with the fact that the bar has a positive bearing at the top, constitute the reasons for its greater strength and resiliency.

The head-free angle bar was a success from the start and demonstrated that better surface could be maintained through its use than by any angle bar that had ever been used by Reading Company.

Some installations were made at about the same time on the Baltimore & Ohio Railroad and in the short space of seven years, the head-free joint in continuous or angle bar form is now being used on the following railroads :

Baltimore & Ohio Railroad.
Boston & Maine Railroad.
Canadian National Railways.
Delaware & Hudson Company.
Erie Railroad.
New York, New Haven & Hartford Railroad.
Norfolk & Western Railway.
Reading Company.
Richmond, Fredericksburg & Potomac Railroad.
Southern Railway.
Southern Pacific Company.
Virginian Railway.
Lehigh & New England Railroad.

Head-free rail.

With the success of the head-free principle established by the Rail Joint Company, it was made possible to effect a radical and complementary change in the rail section. It being no longer necessary to design the under side of the rail head to afford a bearing surface for the angle bar, the idea was conceived that a better shaped and stronger rail section could be designed and without adding to the weight. In effect, a certain amount of metal was taken from the lower corners of the rail head and added to the top, thereby making the rail 3/16 inch higher and increasing the strength as a beam something over 5 % as compared with 130 R. E. section.

It will be seen that the area of wear

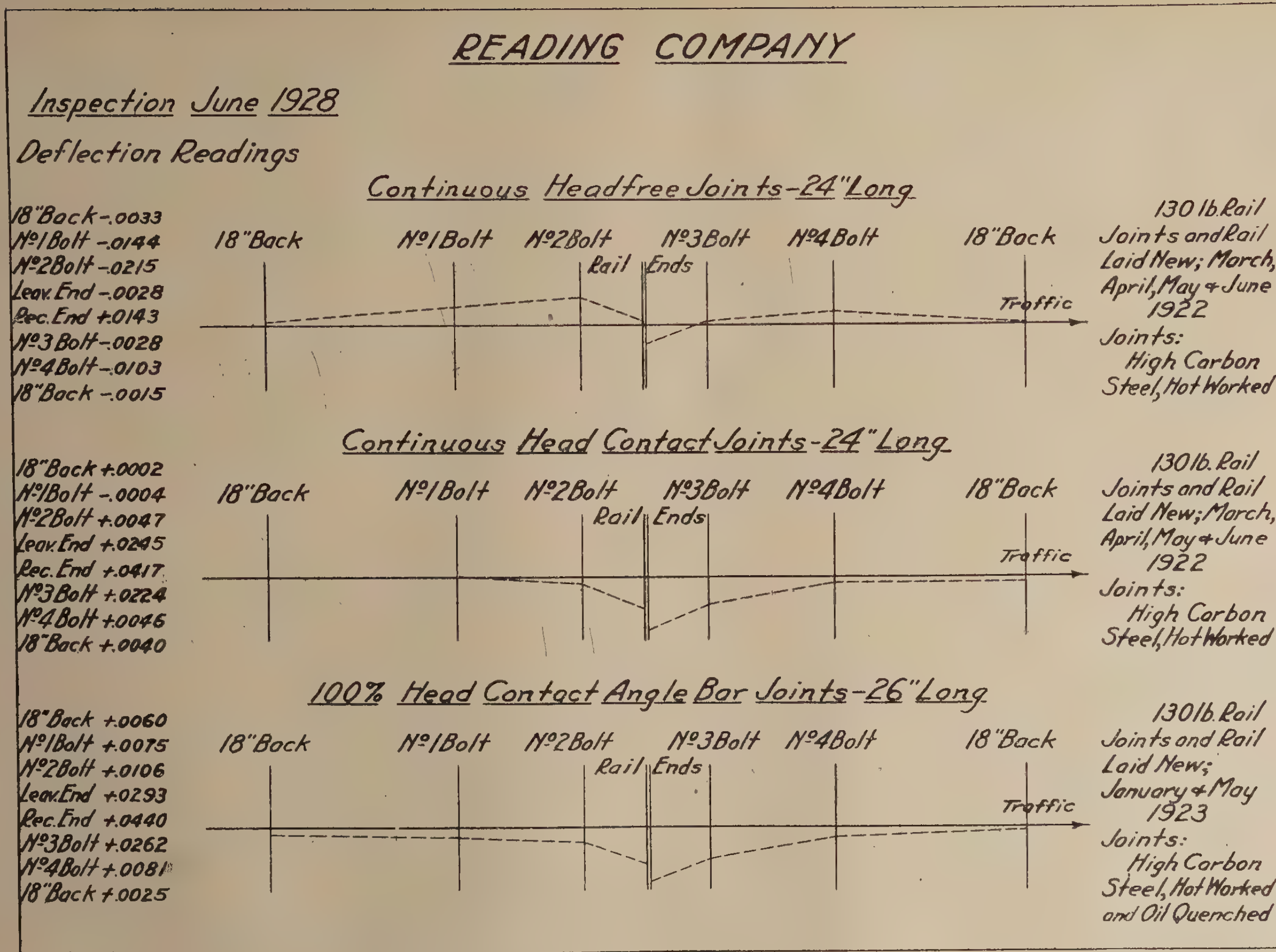

Fig. 3.

SCALE : { Vertical — 1 inch = 0.15 inch.
Horizontal — 1 inch = 6 inches.

has been increased at least 25 % and on the high side of curves this section will not wear to a shelf.

The head of the rail is obviously a better design from a rolling standpoint.

In our humble opinion this rail and angle bar arrangement is the best that has ever been produced and is the most outstanding development of the art.

The following railroads now have head-free rail in track or will in the year 1929 lay a tonnage of same :

Baltimore & Ohio Railroad.
Canadian National Railways.
Erie Railroad.
Lehigh & New England Railroad.
Missouri Pacific Railroad.
Norfolk & Western Railway.
Reading Company.
Richmond, Fredericksburg & Potomac Railroad.
Southern Railway.

Figure 3 is self-descriptive in its titles and shows a summary of deflection readings taken over various types of joints in track at several points along the line of Reading Company.

Note the better surface conditions where head-free joints were in use and this of course has been reflected in decreased maintenance costs and better riding track.

The 100 % joints referred to in comparison refers to a plain re-inforced angle bar without the continuous feature.

More recent readings than June 1928 have not been taken as tests were all completed at that time and conclusions finally reached that resulted in adoption of the head-free rail and angle bar as standard by Reading Company.

CONCLUSIONS.

A. — 1. In heavy duty tracks, use twenty (20) 7-inch × 9-inch cross-ties per thirty-three feet of track. These requirements to be modified for light duty tracks.

2. Rails should be loaded and unloaded by mechanical means.

3. « A » rails should be used in tracks carrying relatively light traffic or tonnage moving at low speed.

B. — 1. Use current specifications and recommendations of the American Railway Engineering Association covering rail chemistry, mill practice and inspection.

2 Head-free rail sections have demonstrated their efficiency and their use should be continued and enlarged.

3. Normal length of rails (39 or 40 feet) should be continued as representing good practice.

4. Rails of greater length should be used to eliminate or reduce number of joints in road crossings, station grounds or other special locations.

C. — Head-free principle in rail-joint design is recommended.

APPENDIX.

Name of railroad.	QUESTION No. 1.								
	Damaged.	Broken.	Flow of metal.	Crushed head.	Split head.	Split web.	Broken base.	Transverse fissure.	Causes of failures.
Wabash Railway.	7	476	45	61	89	38	16	...	Primary causes are inheren defects in the steel, roug handling of the finished rai until the time it is placed i the track, poor track construc tion or maintenance and im proper operation or loading.
Pennsylvania Railroad.	2 300	2 301	427	425	1 039	3 296	395	785	
New York Central Lines.	...	96	...	..	...	...	...	296	Fissures in rail heads pr marily originate in the brittl metal of low ductility in th interior of rail heads. Square breaks generally or ginate and progress from bas seams and develop upwar through the rail section.
Illinois Central Railroad.	...	...	...	2 133	...	278	42	743	Segregation of impuritie blow holes, gas seams, lack ductility and transverse fi sures. Imperfect alignment bolt holes, ties at joints tamp too high or too low. Excessi alternating bending either straightening press or in se vice, seams in base of ra caused by cracks or blow hol opened in the early rolling.
Reading Company.	...	25	...	...	..	...	...	39	

the questionnaire

QUESTION No. 2.	QUESTION No. 3.
Remedies.	Manufacture and inspection.
The use and location in track of classified rail, the reporting of rail failures (after three failures of a given heat number all rails of that heat are removed from track), improvement in roadbed drainage and an increase in ballast section. A more thorough and rigid chemical and physical inspection of manufacture of the steel and rail.	Conditions governing the manufacture and inspection of the rail at steel plants is under the direction of the Robert W. Hunt Company.
For the purpose of reducing the number of breakages and failures this Company has drawn up instructions called « Service assignment of steel rails ». Rails are classified at the manufacturing and separated account of grade of product. Proof tests are required at the mills by the inspectors which define the rails in accordance with these instructions. Highest quality and heaviest rails for heaviest and fastest traffic. See specifications C. E. 55 (c).	Conditions governing manufacture and inspection are set forth in form C. E. 55 (c), which include inspection, proof tests, drop test, chemical and physical and check testing, microscopical and destructional tests.
Improvement of road bed by inserting larger ties with tie plates, stone ballast of increased depth and better drainage. Maintaining proper relationship between wheel loads, speeds of and locomotive counterbalance effect to the rail section, as determined by calculation of stresses in rails. Increased girder strength and stiffness of the heavier rail section and splice bars. Constant study of practices used by various rail mills.	Conditions governing manufacture and inspection are handled by our Inspecting Engineer with his corps. Proof tests at the mill are required for ingot stools, shrinkage, drop and ductility. Weight, branding, straightening, marking and drilling, together with tests on chemical composition are under direction of inspector.
Placing inferior rails from top of ingot only in tangent track on light traffic districts or slow speed tracks. Removing all rails of a heat from main track when four failures account transverse fissures have been reported against it. Canting rails 1 to 44. Rail inspector and supervisor inspect all rail at least once per year.	Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the satisfactory quality of the rails accepted.
We now lay our rails on inclined tie plates, ratio of inclination 1 in 20.	A. R. E. A. specifications and recommendations of practice are followed.

Name of railroad.	QUESTION No. 1.								
	Damaged.	Broken.	Flow of metal	Crushed head.	Split head	Split web.	Broken base.	Transverse fissure.	Causes of failures.
Norfolk & Western Railway.	...	64	...	...	...	...	...	40	Rails improperly manufactured, excess loading, poor joints and tie spacing.
Central of Georgia Railway.	...	13	...	...	113	...	...	19	This Company has taken no steps to prevent rail failures.
Delaware & Hudson Company.	...	...	...	32	...	...	93	60	
Richmond, Fredericksburg and Potomac Railroad.	6	4	...	..	2	4	1	...	
Kansas City Southern Railway.	...	98	2	80	87	21	22	9	
Lehigh and New England Railroad.	...	...	...	...	3	11	1	...	
Lehigh Valley Railroad.	...	...	...	...	...	...	...	43	
Buenos Ayres Great Southern Railway.	...	41	...	...	...	...	...	...	Corrosion by salt air.
Long Island Railroad.	...	76	...	...	...	...	...	...	90 % on account of too many holes (6 hole-splices and bond holes). Small percentage of internal fissures.

QUESTION No. 2.	QUESTION No. 3.
Remedies.	Manufacture and inspection.
Carefully analysing each broken rail in order to determine cause. All rails are inspected by Messrs. Colby and Christie of Philadelphia, Pa. In the use of rails we are keeping 33-inch car wheels below 30 000 pounds.	All rails are manufactured in strict accordance with A. R. A. specifications for open hearth carbon steel.
This company has taken no steps to reduce the number of rail failures.	Rail manufactured under current A. R. E. A. specifications. Inspection to enforce compliance with, under direction of Robert W. Hunt Company.
By inspection at rolling mills and by care in laying in track.	Robert W. Hunt Co. special inspection.
Close inspection at the mill, strict adherence to the specifications. Careful maintenance after rail is in track.	Rolled under A. R. E. A. specifications, inspected by Pittsburg test. Laboratory.
Closer inspection of rail. Reporting of failures. When failures of a given heat are reported (several) all rails of the heat are removed from track.	Rail is manufactured under slighty revised A. R. E. A. specifications. Reputable firm inspects all rail.
Using American Railway Association's 1925 specifications for rail. Inspection at the mill.	Rails rolled by the Bethlehem Steel Co., Steelton. Pa., under usual conditions.
Rail inspectors. When a rail becomes useless on account of transverse fissure all remaining rails in track of that ingot number are removed from passenger tracks.	Rail at present time is ordered according to A. R. E. A. specifications (1925).
Percentages of breakages is insignificant and no special measures are taken.	Inspection takes place in England before despatch.
See Pennsylvania Railroad report.	See Pennsylvania Railroad report.

Name of railroad.	QUESTION No. 1.								
	Damaged.	Broken.	Flow of metal.	Crushed head.	Split head.	Split web.	Broken base.	Transverse fissure.	Causes of failures.
Cordoba Central Railway.	...	...	..	...	...	...	...	...	Not reported.
Buenos Ayres Western Railway.	...	...	3	2	...	1	...	...	Rail weakened by bond holes . . . . 2 Defective joints in two different types of rails . 1 Wear in flange of rail . . 5 Defects in manufacture . 12 Unclassified breakages . . 5 Classified breakages (as noted) . . . . 6 Total breakages 31
North Western of Uruguay Railway.	...	...	...	...	...	...	..	...	No breakages.
Buenos Ayres and Pacific Railway.	..	...	...	...	...	...	...	...	Flaws in material . . . 11 Action of salitre . . . . 3 Total breakages 14
Baltimore and Ohio Railroad.	...	246	...	...	...	..	...	417	Clear breaks. / Transverse fissures. / Broken joints. / Total. 130 lb. rail . 12 / 31 / 21 / 64 100-lb. rail . 234 / 386 / 309 / 929 Total . . . 246 / 417 / 330 / 993 Causes : *a*) Detailed fractures due to temperature cracks, wheel blows, etc. *b*) Transverse fissures. *c*) Clear breaks-brittleness or fatigue. *d*) Rail section weakened by wear. *e*) Joint failures usually caused by worn joint conditions or poor maintenance.

QUESTION No. 2.	QUESTION No. 3.
Remedies.	Manufacture and inspection.
Breakage in standard 70-lb. rail is so rare that no special measures beyond ordinary inspection of track are taken.	This matter taken care of by the London office.
Good line and surface are the measures adopted to reduce breakages, combined with a limit of the axle load allowed to run over light rails. Inspection conditions have not been modified.	Manufacture and inspection at steel plants are governed by the specifications of the Company's Consulting Engineers in London.
Increase the number of ties. Restriction of wheel loads.	Inspections are made at mills by the Company's Consulting Engineers.
Use 130-lb. rail; close inspection at mills during rolling; maintain a high standard of track.	Rails are made under given specifications. Rails are followed by our own inspectors through all phases of manufacture and testing to final classification and acceptance.

Name of railroad.	QUESTION No. 4. Wheel load.	QUESTION No. 5. Cross section of rails.
Wabash Railway . .	The maximum locomotive single wheel load being operated is 33 750 lb.	The given wheel load is operated over first quality 33-foot, 90-lb. A. R. A.-A. standard rail section and 39-foot, 110-lb. A. R. E. A. standard rail section rails.
Pennsylvania Railroad.	The maximum locomotive wheel load is 78 300 lb. and is carried by the fourth driver on the electric type L-5 locomotive. The maximum wheel load for steam locomotives is 76 100 lb. and is carried by the second driver.	The given wheel loads are operated over first quality standard 130-pound rail 39-foot lengths and first quality 100-pound rail 33-foot lengths. Standard rail at present is 39-foot lengths.
New York Central Lines.	The maximum wheel load on our road at the present time is 34 000 lb.	Rail sections carrying this load are 6-inch 105-pound and 7-inch 127-pound Dudley type. The standard length is now 39 feet, prior to 1927 the standard was 33 feet.
Illinois Central Railroad.	The maximum wheel load on this road at the present time is 31 850 lb.	Open hearth carbon steel rails with standard 39-foot lengths. 90-pound and 110-pound rails. A. R. E. A. head, web and base.
Reading Company . .	Maximum wheel load is now 35 230 lb.	Rail section used is 100-pound. Reading section 5 5/8-inches high 33 feet long, and 130-pound H. F. B section 6 15/16 inches high-, 39 feet long

QUESTION No. 6.	QUESTION No. 7.	QUESTION No. 8.
Maximum section.	Cross ties.	Recommended design of rail joint.
The maximum rail section now used to support maximum load of 33 750 lb. is standard A. R. E. A. 110-lb. rail 6 1/4 inches high.	Maximum number of cross ties to properly support our maximum wheel load on a 33-foot is 20.	A joint that has the most efficient and economical distribution of metal to give the required strength. The joint now being used is the 24-inch 4-hole 100 % type with 1-inch × 5 1/2-inch bolts and High power spring washer, with separate tie plate.
The rail section considered necessary for traffic on this road is standard 130-pound P. S. section, having a height of 6 5/8 inches.	Main tracks with heavy freight and passenger traffic : 20 ties are used per 33-foot length rail; for lesser tracks 14 to 18 ties per 33-foot rail. 22 ties are used for 39-foot rails.	The rail joint now being used is the 24-inch 4-hole 100 % type. Weight of both bars 83 lb. This bar takes a 1 1/4-inch × 6 1/8-inch oval head bolt. Separate tie plates are used.
While the 105-lb. section will carry the present maximum axle load, the 127-lb. rail has become the standard for high-speed main line, due to its increased stiffness and higher mechanical properties.	The New York Central Lines standard for 33-foot rail is 20 ties and 24 for the 39-foot rail, which have proven ample for proper load distribution.	The three-tie supported joint has been standard for 20 years. Splice bars are now 38 inches long. All are 6-hole, bolts are 7/8-inch rolled to 15/16-inch over the thread and are 7 inches long. The splice bars and bolts are heat treated. No nutlocks or washers are used. Tie plates are separate and are canted.
Maximum rail section is 110-pound R. E. 6 1/4 inches high.	Cross ties per 33-foot rail required are 20. Ties for 39-foot rail number 23.6.	The angle bar now in use is the 24-inch 4-hole type taking 5 1/2 × 1 1/16-inch bolts. The joint should connect the rails into one uniform girder. It should be strong enough to prevent deformation or taking permanent setting. Hipower nutlocks are used, also separate tie plates.
Maximum rail 130-lb. R. E. 6 3/4 inches high.	Main and heavy duty tracks: 18 ties per 33-foot. Lesser tracks 16 per 33-foot.	Continuous head free angle bars, with 4 bolts. Separate tie plates and Hipower nutlocks. Bars 2 ft. 0 in. long.

Name of railroad.	QUESTION No. 4. Wheel load.	QUESTION No. 5. Cross section of rails.
Norfolk & Western Railway.	Maximum electric locomotive single wheel load is 37 500 lb. Maximum for steam 34 000 lb.	First quality 100-pound A. R. A. type « B » rails 33 and 39-foot lengths, and 130-pound P. S. rails 33-foot and 39-foot lengths. 85-pound rail used for light traffic.
Central of Georgia Railway.	Maximum wheel load 31 100 lb.	First quality 90-pound A. R. A.-A. section 39 feet long.
Delaware & Hudson Company.	Maximum wheel load 36 950 lb.	First quality A. S. C. E. 90-pound rail.
Richmond, Fredericksburg and Potomac Railroad.	Maximum wheel load 34 950 lb.	100-pound O. H. 33-foot A. R. A.-A. rail. 130 pound O. H. 39-foot P. S. rail.
Kansas City Southern Railway.	Maximum wheel load at present is 31 500 lb.	Maximum rail section is 39-foot, 101.5 pound, minimum rail section is 80-pound, 33-foot lengths.
Lehigh and New England Railroad.	2 locomotives with maximum wheel load of 36 500 lb., 7 with 35 300 lb.	Up to 1928 rails were 100-pound 33-foot lengths. Rails are now 130-pound head free, 39 feet long. — R. E. section.
Lehigh Valley Railroad.	Maximum single locomotive wheel load is 34 165 lb.	Standard rail is the 136-pound L. V. section, 39-foot lengths. Adopted 1915.
Buenos Ayres Great Southern Railway.	11 tons maximum wheel load allowed for.	85 and 100-pound British flat bottom rails used to carry load. 40-foot lengths.

QUESTION No. 6.	QUESTION No. 7.	QUESTION No. 8.
Maximum section.	Cross ties.	Recommended design of rail joint.
130-pound rail 6 5/8 inches high is required to support our maximum wheel load.	Standard is 20 ties per 33-foot rails and 24 ties per 39-foot rails.	The most efficient joint we have used is the rail joint 100 % 24-inch 4-hole bar. The 130-lb. takes 1 1/8-inch bolts with spring washers. Separate tie plates are used. The 100-lb. rail bolts are Harvey grip type. No nutlocks.
90-pound A. R. A.-A. section 5/8 inches high.	18 ties per 33-foot length on tangent, 20 on curves.	100 % type of angle bar with reinforced head. Improved Hipower nutlocks, and separate tie plates at the joints.
90-lb. A. S. C. E. rail.	20 ties minimum for 33-foot rail, 24 ties per 39-foot rail.	100 % type joint.
130-pound P. S. rail 6 5/8 inches high is O. K.	18 to 20 ties per rail length.	100 % type head free 26 inches long, 4-hole 1 1/8-inch Hipower nutlocks.
Maximum rail section is 91.5-pound, 6 inches high.	We consider 20 ties per 33-foot length necessary.	4 hole, 24 inch type angle bar with 1-inch heat treated bolts with heavy spring washers.
Maximum rail section now is 130-lb. R. E. section 6 3/4 inches high.	20 ties per 33-foot rail.	Thomson head free joint, 24 inches long 4-hole. Separate tie plates and Hipower nutlocks.
Maximum rail section is 136-pound, 7 inches high.	Standard practice is to use 20 ties per 33-foot length and 24 ties per 39-foot length.	Standard bar at present is 28 inches, 6-hole bolts 6 11/16 inches by 1 1/8 inches. Bars of the future will be 38 inches long. Separate tie plates are used.
British standard rail 100-pound, 6 inches high.	14 ties per 33-foot rail in stone ballast, 16 on earth ballast.	Heavy angle bars 2 ft. 7 in. long with 8-inch angle cut off each end to permit spiking to tie at flange of rail. No. 6, 1-inch pat. Ibbotson bolt nutlock. No separate tie plates.

Name of railroad.	QUESTION No. 4.	QUESTION No. 5.
	Wheel load.	Cross section of rails.
Long Island Railroad.	Maximum weight on single wheel : 30 000 lb.	70-lb. to 100-lb. A. S. C. E. and 100-lb. and 130-lb. P. S.
Cordoba Central Railway.	Maximum axle load for locomotive wheel : 15 tons, 9 cwts.	British Standard Specification steel flat bottomed rail, lengths 33 and 40 feet, weight 70 lb. per yard. Cross-section 45.15 cm^2.
Buenos Ayres Western Railway.	Maximum locomotive wheel load is 9.35 tons.	Plough steel.
North Western of Uruguay Railway.	Maximum locomotive wheel load is 7 tons.	Flat bottomed. 24 feet long, 56 lb. per yard.
Buenos Ayres and Pacific Railway.	Present maximum = 9 1/2 tons. Proposed maximum = 11 tons.	0.45-0.55 carbon steel (max.). Rails 100 lb. per yard, 10 m. and 12.50 m (32 ft. 9 3/4 in. and 41 feet) long. Flat bottom section.
Baltimore and Ohio Railroad.	Approximately 35 000 lb.	Present standard is 130-lb. A. R. E. A section, the use of which is being extended to all high speed and heavy traffic lines. Still use for light traffic 100-lb. A. R. A. « B. ». 90-lb. rail is practically all out of heavy traffic lines.

QUESTION No. 6.	QUESTION No. 7.	QUESTION No. 8.
Maximum section.	Cross ties.	Recommended design of rail joint.
See Pennsylvania Railroad report.	18 ties per 33-foot rail.	Pennsylvania Railroad Standard 4-hole joints with tie plates.
70 lb. per yard.	15 ties per 33-foot rail.	Joint used with standard rail is a 6-hole « L » section fishplate. 7/8-inch bolts and Ibbotson patent lock-nut.
	15 ties per 33-foot rail.	Heavy section four bolt fishplate with heat treated high carbon steel bolts with rolled threads.
4 7/8 inches high. 70 lb. per yard.	13 ties per 33-foot rail.	4-bolt fish plate. 3/4-inch bolts.
146 mm. (5 3/4 inches) high. 100 lb. per yard.	15 ties per 10-m. (32 ft. 9 3/4 in.) rail.	Present standard is the ordinary angle fishplate, 6 bolts 7/8-inch diameter. Ibbotson locknuts. No separate tie plate.
130-lb. A. R. E. A. section. Height : 6 3/4 inches. Base : 6 inches.	18 ties per 33-foot rail. 22 ties per 39-foot rail.	Most recent type is the continuous head-free joint. For 130-lb. rail, bars are 25 inches long; 4 bolts are used. A lock nut without spring washers or other shock absorbers is used. For 100-lb. rail, bars are of same type but are 27 inches long and 6 bolts are used. Two special canted tie plates are used with each joint.

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REPORT No. 1

(**America**)

ON THE QUESTION OF STRESSES IN RAILWAY BRIDGES (SUBJECT III FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION (1),

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Within the intent of this report the term « static stresses » defines what in America are commonly called « dead and live load stresses », that is, stresses produced by the load of the structure itself and by locomotives and trains using the structure, considered as stationary loads, and the term « dynamic stresses » defines what in America are commonly called « impact stresses, these representing the increment to the live load stresses due to the fact that the loading producing the live load stresses is in motion.

The 1906 edition of the American Railway Engineering Association Specifications for Steel Railroad Bridges (2) contained the following impact formula, which had been in use for some years previously :

$$I = S \frac{300}{L + 300}.$$

where :

I = Impact or dynamic increment to be added to the live load stress.
S = Computed maximum live load stress.
L = Loaded length of track in feet producing maximum stress in member.

This formula is commonly known as the « Schneider » or « Pencoyd » formula, and was introduced about 1895.

Between 1907 and 1911 extensive tests were conducted by a Committee which the American Railway Engineering Association delegated to investigate the matter of impact in railway bridges, Professor F. E. Turneaure, Dean, College of Engineering, University of Wisconsin, Madison, Wisconsin, being Chairman. In 1911 that committee submitted a report summarizing the results of its investigation up to that time, which indicated that the maximum impact percentages, as determined by its tests, coincided closely with the formula

$$I = \frac{100}{1 + \frac{L^2}{20\,000}} \qquad \left(I = \frac{2\,000\,000}{20\,000 + L^2}\right).$$

The 1911 report of the American Railway Engineering Association Impact Committee listed causes of impact as follows (1):

1. Unbalanced locomotive drivers.
2. Rough and uneven track.

(1) This question runs a follows : « Investigation into the static and dynamic stresses in railway bridges ».

(2) *Proceedings*, American Railway Engineering Association (A. R. E. A.), 1905, Vol. 6, p. 219.

(1) *Proceedings*, A. R. E. A., 1911, Vol. 12, Part 3, p. 26.

3. Flat or irregular wheels.
4. Eccentric wheels.
5. Rapidity of application of load.
6. Deflection of beams and stringers, giving rise to variations in the action of the vertical load.

The work of the American Railway Engineering Association Impact Committee was continued, under the Chairmanship of Professor Turneaure, and, in 1916, a further report was made. The « Summary of Results », as the same appear in the 1916 report, which are generally identical with those embodied in the 1911 report, are given below [1]:

1. With track in good condition, the chief cause of impact was found to be the unbalanced drivers of the locomotive. Such inequalities of track as existed on the structures tested were of little influence on impact on girder flanges and main truss members of spans exceeding 60 to 75 feet in length.

2. When the rate of rotation of the locomotive drivers corresponds to the rate of vibration of the loaded structure, cumulative vibration is caused, which is the principal factor in producing impact in long spans. The speed of the train which produces this cumulative vibration is called the « critical speed ». A speed in excess of the critical speed, as well as a speed below the critical speed, will cause vibrations of less amplitude than those caused at or near the critical speed.

3. The longer the span length the slower is the critical speed, and, therefore, the maximum impact on long spans will occur at slower speeds than on short spans.

4. For short spans such that the critical speed is not reached by the moving train, the impact percentage tends to be constant so far as the effect of the counterbalance is concerned, but the effect of rough tracks and wheels becomes of greater importance for such spans.

5. The impact as determined by extensometer measurements on flanges and chord members of trusses is somewhat greater than the percentages determined from measurements of deflection, but both values follow the same general law.

6. On account of the influence of the « critical speed », the maximum impact on web members (excepting hip verticals) occurs under the same conditions which cause maximum impact on chord members, and the percentages of impact for the two classes of members are practically the same.

7. The impact on stringers is about the same as on plate girder spans of the same length and the impact on floor beams and hip verticals is about the same as on plate girders of a span length equal to two panels.

8. The effect of differences of design was most noticeable with respect to differences in the bridge floors. An elastic floor, such as furnished by long ties supported on widely spaced stringers, or a ballasted floor, gave smoother curves than were obtained with more rigid floors. The results clearly indicated a cushioning effect with respect to impact due to open joints, rough wheels and similar causes. This cushioning effect was noticed on stringers, floor beams, hip verticals and short-span girders.

9. The effect of design upon impact percentage for main truss members was not sufficiently marked to enable conclusions to be drawn. The impact percentage here considered refers to variations in the axial stresses in the members and does not relate to vibrations of members themselves.

10. The impact due to the rapid application of a load, assuming smooth track and balanced load, is found to be, from both theoretical and experimental grounds, of no practical importance.

(1) *Proceedings*, A. R. E. A., 1916, Vol. 17, p. 116.

11. The impact caused by balanced compound and electric locomotives was very small and the vibrations caused under the loads were not cumulative.

12. The effect of rough and flat wheels was distinctly noticeable on floorbeams, but not on truss members. Large impact was, however, caused in several cases by heavily loaded freight cars moving at high speeds.

While the foregoing conclusions are based, in a major degree, upon the results of experiment and observation, attempts to approach this question from a theoretical standpoint have not been lacking in America, and the results of such efforts are summarised as follows by the American Railway Engineering Association Committee on Impact (1):

1) The theoretical impact effect of a rapidly moving load crossing a span which deflects under the load and thereby forces the load to travel in a curved path, concave upwards. Such a load will exert a certain amount of centrifugal force upon the structure. This effect may be called the effect of speed alone, all effect of counterweight, etc., being eliminated. It has been shown that this part of the impact effect is very small, and may be entirely neglected in spans exceeding 50 feet in length. If properly cambered, this effect disappears entirely.

2) The centrifugal force exerted by the counterweights of the locomotive at high speed. This can be calculated, and will give results of value applicable to stringers and short-span structures. This effect is proportional to the square of the speed. Some attempt has been made to apply results of such calculations to long spans. This is very difficult or impossible to accomplish. It has been clearly shown by tests that for spans exceeding about 100 feet in length, the cumulative effect of the counterweight force is the important thing. About the only result obtainable by applying theory to this condition is to show the evident possibility of high impact results. These high results are limited, however, in a very great degree by the fact that, for the longer spans, the speed which favors cumulative effect is not very high.

Under these circumstances, the Committee is of the opinion that very little aid can be had from theory and that results of experiments must be relied upon. This is particularly true with respect to theories used by various foreign writers, on account of the great differences in working conditions.

(1) *Proceedings*, A. R. E. A., 1916, Vol. 17, p. 119.

The following may also be quoted from the observations of the American Railway Engineering Association Impact Committee, as summarized in the 1916 report (1):

So far as the observations of the Committee go, the maximum impact percentage on all web members (except hangers) is about the same, irrespective of position in the truss. The reason for this is pointed out in paragraph 6, quoted above. However, owing to the influence of the dead-load on the overload capacity of a bridge... and other practical considerations, it is probably desirable to use for all web members a value of L equal to the loaded length for maximum stress. This results in some increase in the size of the web members, particularly near the center of the span, which, on the whole, is a desirable condition. For hangers and floor members, both theory and observation indicate that L should be taken as the loaded length.

For electric locomotives, the rotating parts are well balanced, and the experiments of the Sub-Committee indicate

(1) *Proceedings*, A. R. E. A., 1916, Vol. 17, p. 120.

that the impact under such loads is very small. In fact, what little impact exists would be caused by such features as poor joints and other irregularities in the track or in the locomotive wheels. The impact under electric locomotives is so much smaller than that under the ordinary steam locomotives that the Committee believes that where structures are to be used exclusively under electric traction, the impact to be assumed should be very considerably less than that given by the proposed formula.

In the 1920 edition of the American Railway Engineering Association Specifications for Steel Railway Bridges, the following formula appeared :

$$I = S \frac{300}{300 + \frac{L^2}{100}} \quad \left(I = S \frac{30\,000}{30\,000 + L^2}\right).$$

In connection with the development of this paper, an effort was made to obtain a full expression from all parts of North, Central and South America. Questionnaire was sent to each railroad administration on either continent affiliated with the International Railway Congress, these administrations being distributed as follows :

United States of America and Dominion of Canada	24
Central and South America. . . .	18

Of these, replies were received from the following :

United States of America and Dominion of Canada	12
Central and South America. . .	2

making a total of 14 replies.

Of these, four used the impact formula

$$I = S \frac{300}{300 + L},$$

wich was largely superseded in 1920 by the impact formula

$$I = S \frac{30\,000}{30\,000 + L^2},$$

and this latter formula is used by eight of the other roads responding. Three of the roads furnishing data use various formulas.

Investigation undertaken by the American Railway Engineering Association in 1923 indicates that the Association's Specifications for Steel Railway Bridges of 1920 are largely used throughout the United States and Canada. Replies to a questionnaire on this subject were received from 92 railroads; of these it would appear that the specifications were in use, or proposed for use, by 79 railroads. These specifications provide for the use of the impact formula

$$I = S \frac{30\,000}{30\,000 + L^2}.$$

From the foregoing, it will be noted that, as a result of the questionnaire used in connection with the development of this paper, and also the canvass of the North American situation conducted by the American Railway Engineering Association, the formula

$$I = S \frac{30\,000}{30\,000 + L^2}$$

is in very extensive use, this formula giving an impact or dynamic stress equal to 100 % of the live load static stress at zero span, 75 % at 100 feet span, 42.8 % at 200 feet span and 25 % at 300 feet span.

The progress of human thought is characterized by recurrent phases or periods, and, to this law, engineering research is no exception. Successive generations of engineers investigate identical problems, and, in numerous cases, reach conclu-

sions which, from a superficial scrutiny, indicate the necessity of modifying contemporary practice or standards.

Such discussions have occurred with respect to the engine loading used in the design of railroad structures, column formulas, and formulas covering the impact effect of moving live loads. Although, in many cases, the results achieved are of doubtful value, these discussions have the distinct advantage of concentrating attention upon the subject.

There is no question but that certain contributing factors to impact are susceptible of rigid mathematical analysis and determination. However, the fact remains that there will always be present other factors producing impact, which are not subject to such determination. That is, there is no question but that theoretical mathematical analysis is very valuable and necessary, but there must always be kept in mind the distinction between the theoretical investigator, the designing engineer and the constructing engineer, and also the railroad engineer, who is under the necessity of maintaining in service old and light bridges under the operation of motive power and cars which are constantly increasing in weight and severity of effect on such structures. Conditions of this character must be borne in mind in connection with the study of impact.

Moreover, it is obviously impossible that impact occur in any structure until the stresses occasioned by the dead load and live load occur. In considering this subject, therefore, the object is not alone the development of an impact formula, but the collective results obtained by a summation of the factors of dead load, live load and impact.

The ultimate design of bridges may readily be compared, including live load, dead load and impact, using various formulas for impact, and then equating the ultimate result on the basis of a specific impact formula. For instance, such a study with respect to the impact formula

$$I = S \frac{300}{300 + \frac{L^2}{100}} \quad \left(I = S \frac{30\,000}{30\,000 + L^2}\right)$$

shows that, for span lengths ranging from zero to 100 feet long, not over 3 % total variation in the ultimate design of the structure would be obtained. For span lengths varying from 100 to 200 feet a variation of 9 %, and from 200 to 300 feet a maximum variation of 13 % would be obtained.

In this connection, it is well to note that the vast majority of railroad spans are very short, in fact, a survey of conditions in that part of the United States of America lying east of the Mississippi River and north of the Ohio and Potomac Rivers, which is very highly developed from a railroad standpoint, would indicate that perhaps 97 % of railroad bridge spans are 120 feet or less in length.

Progress is attained only through the free interchange of ideas and experience. However, in challenging a practice already current, every pertinent factor should be carefully weighed. Innovations should be admitted with caution, and, in each case, only after it has been demonstrated beyond all doubt that such a change will be productive of substantial advantages. It is sometimes preferable that practice concerning which question has arisen be retained pending exhaustive investigation rather than subjected to frequent and hasty changes.

REPORT No. 1

(**America, Great Britain, Dominions and Colonies, China and Japan**)

ON THE QUESTION OF THE USE IN RAILWAY WORK OF MACHINES FOR SIMPLIFYING STATISTICAL AND ACCOUNTANCY WORK (SUBJECT XIV FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION),

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Figs. 1 to 14, pp. 510 to 536.

The collection and compilation of statistics is by no means a modern idea. In one form or another the collecting of data has been a fixed governmental function for more than three thousand years. Registration of the population of ancient Egypt, the numbering of the children of Israel, the tax census established by Solon, the registering of births and deaths in the temples of ancient Rome — these are some of the evidences of the recording of statistical information in its earliest forms.

With more highly organized government during the Middle Ages came also the need for more definite knowledge of the financial, military, and political resources of a country. In 1501, there was inaugurated in Augsburg a regular and continuous registration of births, marriages, and deaths. Baptismal records were established in London in 1550, and so-called « bills of mortality », that is, death records, in 1592.

Realizing the great value of facts other than those relating solely to population, Frederick the Great in 1751 ordered an enumeration of all cattle within his kingdom, in 1772 of all the factories and their output, and in 1778 the gathering of data regarding seeds and harvesting.

At the close of the French Revolution, the new government of France was hampered by a lack of census material concerning its population, composition, wealth, and energies. Confronted by the same serious problem, the Federal Government of the United States ordered its first census in 1790, and since then a census has been taken regularly every tenth year.

From that time on, the development of statistics relating to the commercial and industrial life of the United States advanced rapidly. The accumulated material, however, grew to such quantities that correlation of important facts was retarded.

It was largely that condition which gave rise to the need of other than available means to analyze such facts. In 1880, Dr. Herman Hollerith, special agent of the United States Census Bureau, began a series of experiments and developed a system for recording information regarding each individual by punching holes in strips of paper and later in cards. These holes controlled an elec-

trically actuated mechanism which served as a counting or adding device. Thus single classifications of data, or classifications in desired groups, became mechanically obtainable.

Dr. Hollerith's system, when carefully investigated and tested, was found to be so rapid and useful and accurate, and so superior to all other known systems, that it was chosen for compiling the returns of the United States Census of 1890. The success attained attracted widespread attention throughout the world.

With the increasing demands by governmental and industrial officials for statistical information, greater speed and accuracy became necessary in the compilation of such data, and with these demands began the appearance of numerous other mechanical devices, and the punched card system was constantly improved.

While the United States Government was responsible for the invention of electric tabulating and accounting machines, it remained for a railroad to become the pioneer commercial user. In 1896, the New York Central Railroad Company installed a set of these machines for experimental purposes, to determine whether they were adaptable to purposes other than census work; and, from the experience gained there, the practice became widespread until now these machines are in general use.

As in the case of the Government and in all industries, the collection and compilation of statistical and accountancy data constitute a guiding force in the management of the transportation industry. Accuracy and speed usually determine the value or usefulness of the data.

Machines provide a means by which such data can be obtained quickly and economically, without, ordinarily, necessitating a fundamental change in the routine of existing accounting methods. The machine method is generally recognized as providing rapidity and dependability in analyzing such accounting and statistical data as develop in the everyday operation of a railroad.

Because of the great cost in time and money of compiling voluminous figures manually, much desirable and valuable information is never secured where the manual method alone exists, if it is possible to imagine any such situation under the present day conditions. To meet this condition, various machines have been devised to compile and make available the figure-facts of a railroad, which can often be accomplished at the minimum expenditure of time, energy, and money only through some mechanical aid.

The use of machines in railway statistical and accountancy work has not yet made it possible to proclaim the freedom of that work from complexity, intricacy, or elaborateness. Machines have not simplified railway accounts and statistics in the sense of making them less complex. Indeed, it may be urged that machines often present the lure of reserve capacity, which, if utilized, will give added volume or increased production. Yielding to the temptation to obtain more results from the machines is the line of least resistance and probably is followed with some degree of frequency. However, the value of the added statistics or accountancy results so obtained must be measured by their usefulness rather than by the criterion of quantity. The determining factor is the utilization of the statistical or accountancy results — not merely their potentialities in the way of production through mechanical means.

From the standpoint of being an easier

or shorter process for doing railroad statistical or accountancy work, machines are, speaking broadly and generally, productive of simplification. In other words, the use of machines simplifies the method of compiling.

It remains for every railroad to decide for itself what machines, if any, to use in simplifying its statistical and accountancy work. Conditions vary; the needs and demands differ on various railroads, and there are many factors to be considered. The machine that is particularly adapted to the requirements of one railroad may not necessarily be a success on another railroad. On the other hand, some machines attain general widespread use and acceptance. All that has had the effect of encouraging inventive genius and promoting research into and the development of machines adapted to railroad office use. Consequently, those interested in such machines, from the standpoint of utility, usually have a wide range of choice, depending much upon the needs, demands, and conditions to be met.

Efficiency and economy — these two words constitute the controlling and impelling reasons for the use, by railroads, of machines in simplifying statistical and accountancy work. However, that generalization is subject to some qualification as well as some amplification.

Usually a machine is no more efficient than its supervision or its human operator. It does not necessarily follow, therefore, that the adoption of machines promotes efficiency, for the human factor must be taken into consideration in that connection, although obviously many machines do possess advantages or elements of efficiency superior to what would exist if no mechanical means were utilized for the same purpose.

The economy effected by the use of machines in simplifying statistical and accountancy work is sometimes real, tangible, and convincing; is sometimes elusive, intangible, and difficult or impossible of demonstration; is sometimes nonexistent, but even that situation is not necessarily subject to warranted criticism under all circumstances. The reduction of the nerve-racking monotony incident to clerical work is frequently regarded as sufficient justification for the installation of machines.

Punched hole accounting.

Tabulating machines, together with punching and sorting machines, perform the essential operations encountered in railroad accounting or statistical work. Those operations consist of preparation of underlying data, sorting the data into classes, and tabulating or totaling the data in each class. The punch machine performs the function of compiling the detail through the process of punching the data on cards. As the name indicates, the sorting machine sorts the data into classes, while the tabulating machine obtains the totals for the different classes.

Punched hole accounting is a notable advance in connection with railway accounting and statistics. The fact that statistical information regarding a person or a transaction can be transcribed to a card by means of punched holes and this information, with economy of time and labor, can then be tabulated, by means of mechanical devices, and produce any desired statistical result, has caused widespread use of the punched card method in railroad offices in place of written transcripts.

The flexibility of figures and the unlimited possibilities in the combination of numerals are utilized in punched hole

accounting. The necessary or desired figure-facts can be recorded in such detail as will produce an imposing array of different kinds of data pertaining to the same transaction from a card containing either 34, 45, or 80 columns.

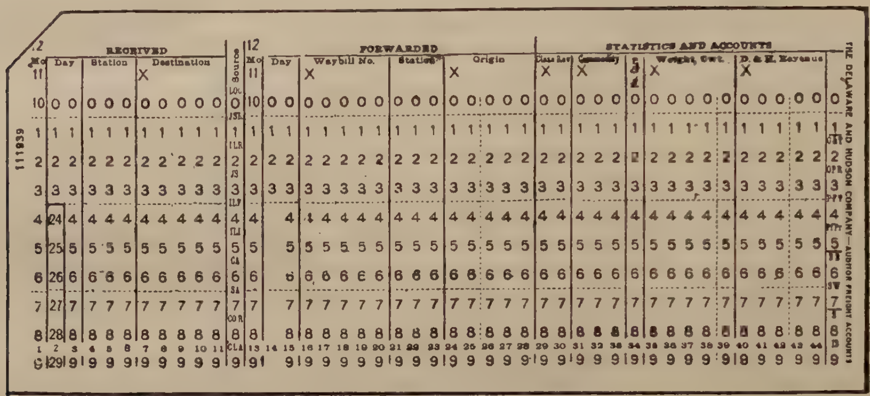


Fig. 1. — A typical tabulating card.

The basic principle of punched hole accounting is the translation of any given written information into numerals. The first step in the operation of this method is to devise an adequate system of number symbols depending upon the purpose for which, or the extent to which, the machines are used; that is, accounts are designated by one set of numbers, states or provinces by another, operating divisions by a third, accounting divisions by still another set of numbers, and so forth. Thus, each class of information has a particular set of numbers assigned to it.

The data in detail, such as account numbers, charges to accounts, or other information, are punched on each separate card by means of the key punch machine, which is operated in much the same manner as a nonlisting computing machine.

The cards are especially printed and particularly designed for use in connection with the tabulating machine system, and are of uniform size and thickness.

As a means of indicating their position, any one of the four corners of the cards is clipped, a different corner being cut if the same form is used for various classes of data. If a corner then protrudes, it is evident that a card is out of position or included in the wrong group.

Cards are divided into « fields » by drawing vertical lines between the rows of digits printed on the cards. The following illustration will show the first step in designing a tabulating card : A line drawn between the first and second rows of digits on the left-hand side of the card gives us one field or 12 recording positions for indicating the 12 months of the year. These positions are known as recording positions, to differentiate them from the adding fields on a card, as there are 12 recording positions and 9 adding positions, excluding zero, on a tabulating card. By drawing a line between the third and fourth rows of digits we have another field, consisting of two rows of figures, which can be used for indicating the 31 days of the month. This same

process may be continued for recording other needed data.

The act of drawing a vertical line, therefore, automatically transforms a plain card with 45 or 80 columns of figures into an accounting or statistical record of astounding flexibility. The accuracy of the record cannot be questioned, as a hole once punched is not subject to transposition or change, which is possible where figures are recorded or listed manually.

A record of this kind makes it possible to store information for monthly, quarterly, or other future use, and the rapidity with which facts can be recorded through the use of punched holes permits the accumulation of all data for each transaction.

Written data and various classes of statistics can be recorded on tabulating cards, and a constant reanalysis or breaking down of accounts into subdivisions continued almost indefinitely, permitting diverse studies or analyses of the same figures from different view-points, thus indicating the flexibility which has been made possible through the combination of tabulating mechanisms and punched cards.

Broadly speaking, there are two types of tabulating machines : one electrically driven and electrically operated, and the other electrically driven and mechanically operated. Within the limits of this paper, both types cannot be discussed or treated. It is, therefore, necessary to confine the discussion here to one type, although this should not, of course, be construed as indicating any preference, the choice being dictated by necessity and in no way based on the relative merits of the two types. Furthermore, the type of tabulating machines hereinafter described will not receive exhaustive treatment; there is more that can be said. Sufficient description is given, however, to indicate the general principles — and much is left to the imagination, judgment, and discretion of the individual.

Tabulating cards, individualized. — Tabulating cards are available in colors, in order to differentiate between classes of statistical or accountancy records. Color striped cards are used for this same purpose and offer a wide range of individualizing records. When conditions necessitate a still greater range, striped colors are utilized in conjunction with colored cards, but care must, of course, be exercised in such cases to secure contrasts. A green stripe on a green card, for instance, even though the shade of green is slightly different in both cases, would not supply a sufficiently strong contrast to be of practical service. The best results in striping are secured from solid tinted stock striped with a different color.

Key punch machine. — In the manually operated key punch, the depression of a key results in the punching of a hole in a card and causes the card to move forward to the next punching position. In this way, information is recorded on tabulating cards by means of punched holes. Proficiency in the use of the punch machines is quickly acquired, and the information is transcribed to the cards with almost miraculous ease and rapidity.

Key punch, electric. — The purpose of the electric key punch is the same as that of the manually operated machine and the method of handling is quite similar. Only a slight depression of the key, however, is required. The electric current

pulls down the key, the hole is punched, the key is released, and the card moves forward to the next punching position.

Electric duplicating key punch. — This machine records data on tabulating cards in the same manner as the two machines

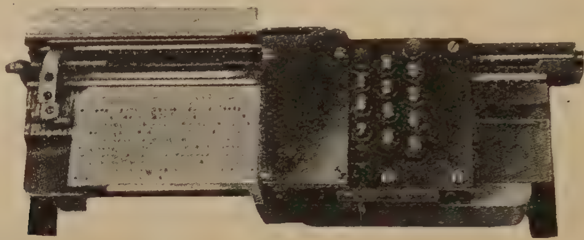


Fig. 2. — Electric key punch.

already described. It is so designed that all information common to more than one card is recorded automatically. Any card in its entirety, or any portion of it, can be duplicated with absolute accuracy and great rapidity. The device can be used as an individual card punch, for punching cards singly, or it can be used for duplicate punching. When either the whole or only a part of the punching is to be duplicated, a master card is inserted in the rear carrier with the information recorded which is common to a number of cards, and the machine automatically punches holes in the proper position on separate cards in accordance with the perforations appearing on the master card inserted in the rear carrier. When the fields in a card, which are to be duplicated, have beeen punched, the punch automatically stops, and specific information pertaining to a section of the card, for a certain transaction, is punched by operating the keys in the regular manner.

The punch has a self-feeding mechanism and automatically places in position the cards which are to be punched, when the card carrier is placed in punching position. The duplicating of perforations is based entirely upon the holes in the master card in the rear rack, which insures absolute accuracy and uniformity of the punched information common to all cards.

When desired, cards of different form or color may be fed directly into the punch without removing or in any way disturbing those in the magazine.

Verification key punch. — In operation the verification punch is like the key punch, but its purpose is to verify the accuracy of key punching. After cards have been perforated, the punching is verified by merely inserting the punched card in the verification punch in the same manner as was done when the cards were originally punched. The verification consists of the operator depressing the corresponding keys in the verifier for the information appearing on the records from which the cards were originally punched. If the original punching is correct, the carriage and car will move forward to the next punching position in the same manner as was done when the card was originally perforated. But if the card is incorrectly punched, or if a wrong key is depressed on the verifier, the card and carriage remain stationary. The verification punch, however, is not

generally used, as the punch operators become so proficient that punching is accurate and any possible errors can be readily located through the use of control figures for the various classes of statistics compiled.

Automatic gang punch. — The automatic gang punch is exclusively a recorder of common data. It is entirely automatic in operation and records all pertinent data at the rate of 125 cards per minute.

The punching dies can be set up manually by means of keys, or automatically through the use of a punched and verified master card. Either method guarantees accurate duplications.

A feature of the automatic gang punch is the automatic shut-off, which stops the feeding mechanism when a predetermined number of cards has been punched.

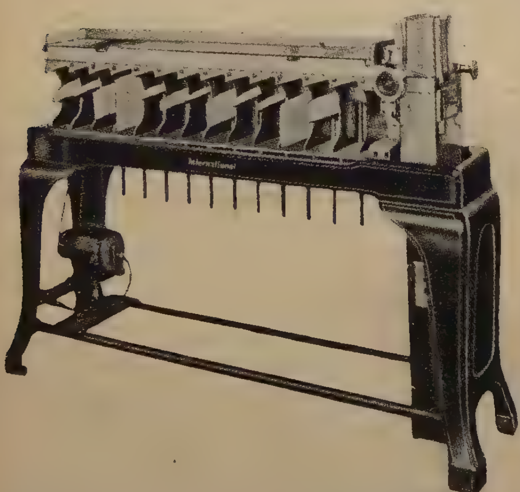


Fig. 3. — Electric sorting machine.

Electric sorting machine. — The sorting machine assembles all cards for each class of information and simultaneously arranges the various classes in numerical sequence, no matter in what order they may be. The machine is used for sorting information or segregating data into groups or classifications. The sorting machines are made in two models, horizontal and vertical. Where conservation of room is necessary, the vertical type machine is more desirable, as it requires less floor space.

Electric tabulating machine. — The tabulating machine is used for totaling large groups of cards covering similar classifications of data. The totals of quantities and amounts punched on the cards are registered on counters. The machine adds simultaneously from one to several columns of figures at an astonishing rate per minute for each counter.

There is a nonprinting type of tabulating machine which has a wide range of uses in all classes of tabulating work. It is particularly adapted to those instances where the classes of information are numerous and the cards to be tabulated in each class are few. The machine may be set to secure subtotals and grand totals.

The printing type of tabulating machine adds the quantities and amounts punched in tabulating cards in the same manner as does the nonprinting machine, but differs in that it makes printed records directly from the punched cards. When group totals only are desired, the machine adds from one to several columns of figures simultaneously. When detailed analyses are required, this machine can be transformed instantly into a listing machine capable of printing from one to several itemized columns of figures, together with group totals. Ruled report forms can readily be inserted in the machine and finished reports secur-

ed in printed detail directly from the punched tabulating cards. Carbon copies can be secured.

Applications.

The applications of tabulating and accounting machines in railroad work are so numerous that only a partial list of those found in the countries covered by this report can here be given. The Delaware & Hudson Company, one of the pioneer railroad companies of America, may be taken as an illustration of an extensive user of machines for accounting and statistical purposes. At the present time, machines are being used, or their use is contemplated, by that Company, for operations such as :

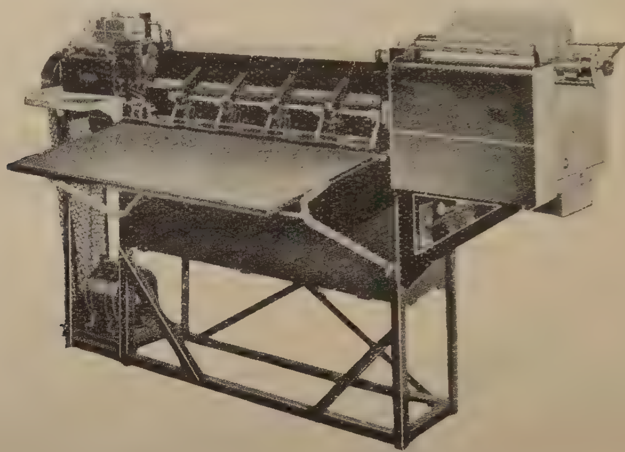


Fig. 4. — Printing tabulating machine.

- Timekeeping — Transportation, Maintenance, and Motive Power Departments — and the preparation of payrolls applicable thereto.
- Distribution of labor charges to primary operating expense and other accounts.
- Compilation of labor statistics pertaining to wages, classification of employes, group insurance, etc.
- Preparation of bills versus other lines for repairs made to their cars.
- Compilation of freight commodity, tonnage, and various traffic statistics.
- Determination of interline forwarded and interline intermediate freight revenues.
- Verification of freight settlements made by other carriers.
- Compilation of statistics incident to overcharge and loss and damage freight claims.
- Compilation of locomotive, train, car, and ton mileage statistics.
- Maintaining station freight accounts in general office.

In Japan, the Imperial Government Railways have their main equipment of accounting machines at Tokyo, with smaller installations at six divisional accounting offices. Daily accounts of freight movements are made and statistics related to ton-mile movements, commodity

statistics, and traffic density statistics are extensively prepared by machines. It is proposed to utilize machines in connection with passenger traffic statistics also.

The South Manchuria Railway is waking a study and carrying on experimental work in an effort to adapt machines to their needs.

In Argentina, Brazil, Chile, Cuba, and Mexico, tabulating machines may be found in the accounting offices of many of the railroads operating in those countries, for compiling statistics and for freight accounting.

In Great Britain, Dominions and Colonies, machines are extensively used for practically the same purposes as in the United States. Some of these purposes have already been mentioned, but there are many other operations for which tabulating machines are used in America and Great Britain, of which the following may be noted :

- Verifying station agents' daily or monthly abstracts of local and interline waybills forwarded and received.
- Balancing local advances and prepaid forwarded with the received.
- Balancing advances and prepaid forwarded as reported by other carriers with station agents' interline forwarded abstracts.
- Balancing freight advances and prepaid as reported by station agents on interline received abstracts with interline freight reports rendered to foreign carriers.
- Verifying switching settlements with per diem reclaim statements and interchange car reports.
- Distribution of all debits and credits to operating and other accounts from which the monthly analysis of operations is compiled; also compiling operating results by divisions.
- Preparation of and accounting for employes' pay checks.
- Distribution of voucher, bill, and material charges and credits.
- Obtaining record of equipment for purposes of typing loose-leaf unit record of locomotives and cars, the cards being used as a working medium for depreciation reports, annual, and valuation reports, etc.
- Material accounting through the use of a combination requisition and punch card, the material being ordered on information posted to the card and the card punched when received in the accounting office from such information; also results of inventory tabulated in similar manner from cards showing actual count of material at locations.
- Personnel records.
- Compiling station reports for regulatory bodies.
- Compiling annual reports for taxing authorities.
- Compiling passenger statistics.
- Compiling statistics relating to accidents, failures on account of defective rails, wheels, or other causes.
- Compiling statistics relating to fuel and lubricant consumption.

Procedure.

In order that a clearer conception may be gained of the exact procedure in the case of some of the major applications of the punched hole method, there is incorporated in this report, in Appendix A, a detailed account of the procedure involved in time-keeping, the preparation of payrolls, and the distribution of labor charges; and, in Appendix B, the procedure for the preparation of freight commodity statistics, as followed in the accounting offices of The Delaware & Hudson Company. There is also added, in

Appendix C, a description of a station accounting plan, largely conducted through the use of machines — a plan prepared by the Railway Accounting Officers Association, whose headquarters are located in Washington, D. C., and whose membership extends to a number of countries throughout the world.

Calculating machines.

For our purposes, this general heading will be considered applicable to machines that multiply, divide, and subtract, adding machines, listing and nonlisting; computing machines, etc. Brief mention will be made of some of the machines and their uses, but none of them can, for obvious reasons, be comprehensively treated within the limits of this paper. At best, therefore what follows can be merely indicative.

Adding and listing machine. — Such machines are operated by depressing keys and pulling a handle or pressing a bar, if motor-driven. They record the figures on paper tape or sheets of paper and are utilized when necessary to have a permanent record of items. In general, they are employed in :

- Listing open items in proving balances in ledger account (reconcilements). The drawing off on work sheets and footing work sheets is thus avoided. By using a wide machine, the numbers and amounts of vouchers, bills, or pay checks can be drawn off at the same time.
- Listing material requisitions by classes, accounts, and accounting divisions for charge and credit and for statistical purposes.
- Listing pay checks, time checks, vouchers, or similar items.

Duplex adding machine. — The duplex or two-counter adding machine is equipped with two adding counters, one upper and one lower, permitting two separate totals to be accumulated simultaneously. A lever is attached to the keyboard which throws either counter into operating position, but only one counter can be active at any one time. While one counter is in a position to add, the other becomes inactive. Having accumulated a total in the upper counter, it is possible to transfer the total to the lower counter and thus make up a grand total. Amounts can be added in the upper and lower counters alternately.

Adding machines with word-printing devices, shuttle carriage, tabulators, and other devices. — There are types of adding machines which have word-printing devices attached to them, thus enabling an operator to print dates, months, billing, and bookkeeping terms opposite printed numerals, while others have some 20 or 30 different characters or symbols which can be so utilized.

Still other types are equipped with a shuttle or movable carriage and tabulators similar to a typewriter, so that amounts can be printed wherever the operator desires, and various split totals accumulated.

Machines especially adapted for multiplication, division, addition, or subtraction. — Such machines have a full flexible keyboard, through which factors are set. Automatic multiplication is accomplished through special rows of keys 1 to 9. To multiply by 9, you press No. 9 key, the machine operating nine times, stopping automatically. By touching a button, the machine automatically clears.

One kind of machine is nonlisting, both product or quotient and multiplier or divisor being recorded on the dials, while another kind is nonlisting and operated

in the manner already indicated, except that numbered keys are used instead of levers for multiplicand or dividend.

A nonlisting motor-driven machine is operated by depressing a key for multiplicand, multiplier, dividend, and divisor, and the results are recorded on dials. The carriage is automatically shifted for each unit.

Another type of machine is operated by setting markers for divisor, dividend, multiplier, or multiplicand and turning the crank, or, if motor-driven, by pressing the bar. It requires but one operation for each unit. The figures are recorded on dials.

Nonlisting computing machines. — Such machines are operated by hand pressure on keys, the figures being recorded on dials when the keys are depressed. They are used for multiplication, addition, subtraction, and division. The best results are obtained by assigning permanent female operators and training them to operate by the touch system. There are nonlisting adding machines, which are operated by setting keys and pulling a lever, the figures being recorded on dials. They may be operated by inexperienced clerks; an expensive machine may thus be used for general purposes and shifted from desk to desk as needs require.

Nonlisting computing machines are used for many operations, some of the most common uses being the following :

- Making and verifying extensions and footings on vouchers, bills, payrolls, and statements.
- Prorating common operating expenses between operating divisions, accounting districts, states, or classes of service.
- Compiling train, car, gross, and net ton-miles in division accounting offices from wheel reports.
- Arriving at total of pay checks and drafts.
- Totaling requisitions and invoices as a check against adding machine tapes, when list is necessary, to avoid calling items back against tape.
- Cross-footing and balancing monthly statistical sheets to arrive at total for year, avoiding necessity of drawing items off on a work sheet.

Charts used in connection with nonlisting computing machines. — As a means of symplifying computing machine operations, an extensive line of charts and tables is in common use. Among others the following might be mentioned :

- Payroll table decimal equivalent of days for 24 to 31 day month.
- Rate per minute for each hourly rate.
- Reciprocal table where constant divisor is used.
- Discount table, showing net of $1.00 after discounts are taken off.

Central bureau nonlisting machines. — In many railroad accounting departments all the nonlisting machine work is centralized in one department in which none but female operators are employed. Practically all computing machine work for an entire departmental office is then performed in this central bureau. Such an arrangement permits training operators on all classes of work and reduces waste time to a minimum.

Typewriters.

Although typewriters are utilized for innumerable purposes, they serve principally for correspondence, statement work, and what might be termed general use, such as preparation of bills, vouchers,

waybills, etc. For statement work, the machines are usually equipped with tabulators. Typewriters are often utilized for posting or writing in loose-leaf records, and the flat-writing typewriters find similar uses in bound books or records. The typewriter, when equipped with two kinds of type, one plain and one pinpoint, can be advantageously employed for writing drafts, checks, and other negotiable paper. A machine thus arranged becomes a typewriter combined with check protector. The name and address is written with the plain type, while the amount is written with the pinpoint perforating type, to guard against manipulation.

The preparation of waybills, by the use of typewriters, is illustrative of one kind of simplification attained in railway accounting through the utilization of machines. The waybills thus prepared are more legible, and, therefore, more readily and accurately read by trainmen and others — facilitating the handling of freight. The advantages to the agent at destination are of a similar nature. In the accounting departments, the auditing of the waybills is accomplished with more speed and accuracy than would exist if the waybills were not prepared by machine. The carbon copy of a waybill prepared on a typewriter is, or should be, clear and legible, eliminating the blurred appearance of a copy of a waybill obtained by means of the copy press.

The advantage of legibility, incident to the preparation of waybills on the typewriter, applies with equal force to various other documents, such as freight bills, checks, drafts, or reports of all kinds.

The use of the typewriter has created widespread adaptability of the carbon process in producing copies and in preparing various underlying forms at one writing. The labor of inserting carbons is intended to be eliminated by the manifold system, and there are several different types of machines designed for typewriting manifold forms.

Typewriter with adding machine attachment (motor-driven). — For statement, bookkeeping, and other general work where it is necessary to foot typed figures, and cross-foot and carry an accumulation of totals, a typewriter with adding machine attachment is very advantageous. The separate operation of footing the completed statement after typing is thus eliminated.

Combined typewriter and computing machine. — An electrically operated combined typewriter and computing machine has four accumulators, adds, subtracts, multiplies, and divides and is specially adapted to bookkeeping, statement work, and the rendering of bills.

Typewriter — flat writing. — A special type of machine is used when the statement or record sheets are too large for the ordinary wide carriage machine, or when it is inadvisable or impossible to roll the sheets through the machine, or when posting is to be made to bound books.

Typewriter cyclometer. — This device is attached to typewriters to record the output and determine the efficiency of individual operators. It records the number of key and space bar strokes.

Line-a-time. — A device attached to the desk of the typist directly behind the typewriter and facing the operator, known as the « Line-a-time », is equipped with a lever-operated guide for following the line, eliminating the necessity of using

a rule or other flat instrument for that purpose.

Planographing or photolithography.

A type of mechanical method providing simplification for railway statistical and accountancy work is known as photogravure, photolithography, or planographing, these three terms of ten being used synonymously.

The term « photogravure », as used in this connection, is intended to indicate the process for making prints or printing from an intaglio plate prepared by photographic methods.

« Photolithography » would indicate a combination of photography and lithography, but printing is also included in the process.

« Planographing », which is the term generally used in railroad parlance,means the process for printing from a flat surface, but that should not be regarded as a definite limitation. The plates used in the planographic process may be circular or in any form necessary for printing.—

In the planograph process the prints are made from a zinc plate prepared from or by photographic methods. The original (which may be typewriting, handwriting, printing, or other form of reproduction) is placed upon a board, under a powerful light, and photographed with a large camera which has a prism attached to the front of the camera. This prism causes the photograph to be taken right side up on the negative plate. This negative is touched up, when necessary, so that the letters or figures will all be clear. Then the plate is placed upon a piece of zinc which has been treated with chemicals. The light, going through the negative, transfers the image to the zinc plate, which is treated further so as to have the image take the ink in printing. Lastly, the zinc plate is placed on the press and the ordinary process of press work (printing) with a plate completes the process.

The process is particularly useful in the interest of accuracy, as it eliminates any necessity of proofreading. The reduction in size possible by reason of the photographic part of the process offers many practical advantages.

Standardization of forms.

An important factor in the use of machines for railway accounting work is the standardization of forms that are interchanged among carriers, including reports made to the carrier by other carriers. This may be illustrated by the following : When two or more carriers are interchanging freight, and the waybill goes through to final destination, it is obvious that such waybill is prepared primarily for the use of some other road and not for the convenience of the road which makes or prints the waybill form. Therefore, the blank must be uniform in size and arrangement, so that any particular information will always be found in the same place on the forms of different carriers and so as to facilitate filing, reference, etc.

Miscellaneous machines.

In a report on machines for simplifying statistical and accountancy work one should not fail to make at least passing reference to various miscellaneous mechanical devices that are being used by railroads. While some of the items included in this report may seem unimportant, it is thought that a record of this sort in the *Bulletin of the International Railway Congress Association* will serve as an interesting mirror of the status of machines and mechanical devices in rail-

road accountancy work during the period of 1925 to 1930. Considering the rapid progress in the development of machinery in other fields in our age and realizing the infinite resources of the human mind in inventing new devices, it is conceivable that a reporter for a future congress, writing on this same subject, will turn back to this record and by comparison be able to chronicle a remarkable advance over the methods and devices of this day.

Dictating and transcribing machines. — For general correspondence purposes, letters are dictated into these machines and recorded on wax cylinders. The cylinder is then given to the operator who slips it on the transcribing machine and, as the dictation is reproduced, types the dictated matter on the typewriter. Telegrams and mailgrams are dictated on separate cylinders to permit preferred attention and expedite transcription. This method eliminates the time lost by stenographer when taking dictation direct from correspondent. After the letter has been transcribed, the cylinder is shaved and used over again. All transcribing is sometimes done in a central bureau. The cylinders are collected at stated periods and delivered to the transcribing department.

Mimeograph. — Mimeographing devices are used for obtaining a number of copies of circulars, statements, etc., by means of stencils cut on a typewriter.

Dermatype stencils. — When an unusually large number of copies are required, dermatype stencils are sometimes employed. Such stencils can be cleaned and filed away and additional copies run off when desired.

Gelatin duplicator. — Gelatin duplicators are used for preparing a small number of copies of circulars or statements. The statement or circular to be duplicated is prepared either by hand or on typewriter with specially prepared ink or ribbon and applied to gelatin surface. Copies are then obtained by applying blank sheets to impression left by original or master sheet. The duplicating surface comes in rolls and after one surface has been used a new one may be obtained by turning a handle.

Clay duplicator. — This device consists of clay composition contained in a tray. From 5 to 50 copies can be obtained in the same manner as on a gelatin duplicator.

Multigraph. — A multigraphing device requires setting of type. It is used for producing circulars, imitation typewritten letters, statements, or other matter.

Addressing machine. — For rapid addressing of envelopes, printing names on time slips, time rolls, etc., various types of addressing machines are found.

Graphotype machines. — Metal plates for use in addressing machines are cut by graphotype machines, although stencil plates may be utilized on some types of addressing machines.

Mail opener. — This is a mechanical device used for opening incoming mail, by slitting the envelopes.

Numbering machines. — These machines are used for numbering consecutively. There is also a combination dating and numbering machine, which dates and numbers consecutively in one operation.

Clock time daters. — For stamping date and time received on correspondence, statements, or other matter, vari-

ous models of clock daters are in common use.

Radial distributor. — This is a fan-shaped device with receptacles into which papers are dropped when assorting either in alphabetical or numerical order.

Signograph. — A signograph permits signing a number of checks, vouchers, or drafts at one operation.

Check protectors. — Various models of check protectors are to be found which insert amounts on negotiable paper in such a manner as to prevent manipulation.

Air tubes.—Telegrams are transmitted by means of carriers through tubes to and from telegraph office. Special letters (relayed through telegraph office) to other offices in the same building are also sent in that way.

Automatic electric elevator. — For transmitting mail and other articles to various offices, there is an automatic electric elevator which is operated by pressing a button. The car is controlled from, and may be stopped at, any floor.

Electric mail elevator. — In some general office buildings an electric mail elevator is operated between the central mail room and all floors in the building. It is used for delivering large quantities of mail to and from the mail room from where the car is controlled.

Mail chute. — In other buildings there is a mail chute leading to a central mail room. There is a letter-drop on each floor and small quantities of outgoing mail are sent to mail room through chute.

Mailing devices. — Various mechanical devices are used for mailing, such as, machines for affixing postage stamps, scales for weighing mail, electric sealing wax pot or devices, etc.

Mail carriers. — Mail to be transmitted between accounting office and other departments is placed flat in a carrier without being enclosed in envelopes. The carrier is made of heavy cardboard covering with canvas and has a double flap, on one of which is printed the accounting office address and on the other the address of the appropriate department.

Package sealer. — Sealers are used for wrapping packages of tickets, baggage checks, meal checks, etc., instead of using cord or rubber bands.

Paper fasteners. — One type of machine makes staples from length of wire wound on cylinder inside of machine. There are various machine, as well as manual, methods for this general purpose.

Rubber stamps. — Rubber stamps are very generally used to save the time incident to writing. Around the edge of stamp may be shown in very small type the initials of the various desk heads to whom mail is generally distributed, or desk numbers may be substituted for initials.

Time clock recorders. — The time of arrival and departure of clerks employed in offices is recorded on cards. They are also used for obtaining a record of the time work was started and completed in connection with the output of non-listing machines and determining the efficiency of individual operators.

Paper punch.—For perforating papers that are to be filed, various types of paper punches are in common use.

Binders. — Waybills, payrolls, vouchers, and similar papers, are bound in

binders with heavy hinged cardboard binding sides. Holes for binding purposes are cut in records by drills, either hand or motor-driven.

Dictograph interconversing system. — This installation consists af a master station in the chief accounting officer's office to the several branches of the accounting department. It permits conversation individually or collectively.

Cancelling machines. — There are motor-driven machines for cancelling, by small perforations, paid pay checks, drafts, vouchers, voucher attachments, etc. The dies can be set to show the date of payment. They are used also for perforating tickets, excess baggage scrip and book covers, baggage checks, meal tickets, etc., received from agents, conductors, and other carriers, thus making impossible their misuse. There are some hand-operated cancelling machines which cut a round or square hole.

Cylindrical slide rule. — This device consists of a cylindrical slide having both rotary and longitudinal movement within an open framework of equidistant bars. The slide contains two logarithmic scales, one on each side of center. On the bars are two other scales arranged in the same manner as on the slide. It is used for computing and proving averages in statistics, as well as for computing and verifying percentages, prorating revenues and expenses by states or divisions, and apportioning charges for locomotive repairs to classes of service. It does the same class of work as multiplying and dividing machines with greater speed, but the results are not so accurate beyond four figures.

SUMMARY.

1. The use of tabulating machines for simplifying railway statistical and accountancy work dates back to about 1896.

2. So-called punched hole accounting represents the greatest advance thus far achieved in this field, particularly for the reason that it comprises the fundamental operations incident to railway accountancy and statistical work.

3. The applications of the punched hole method to railway statistical and accountancy work are very numerous and diversified.

4. The simplification of railway statistical and accountancy work is only a relative term and therefore not susceptible of dogmatic conclusions.

5. Mechanical devices and appliances of almost every character are used in railway work for simplifying accounting and statistics, but with the continual invention of new devices it is evident that further advance will still be made in this respect also. The price of progress is change.

6. The reasons actuating the installation of mechanical devices differ and therefore do not lend themselves to a generalization.

APPENDIX A.

Timekeeping, payrolls, and labor distribution.

Under the plan of keeping time, preparing payrolls, and distributing labor charges by use of machines, as followed by The Delaware & Hudson Company, the following kinds of equipment are required :

Plate cutter,
Addressographing machine,
Electric key punch,
Verification key punch,
Electric duplicating punch,
Electric tabulating and printing machine,
Electric tabulating machine,
Electric sorting machine,
Calculating machine,
Portable card rack,
Filing equipment.

Upon entering the service, each employe is assigned a working number and throughout the machine accounting identification is by number rather than by name. Assignment of working numbers is so arranged that each operating division has a series of numbers not conflicting with those of other divisions, so that with information at hand as to an employe's working number and department, the division on which he is employed can readily be determined.

In the Mechanical Department and in station and yard service of the Transportation Department, this plan is further extended to locations. In the Maintenance of Way Department, where the force turnover is heavy at times, to indicate gang or location by a series of working numbers would occasion the assignment of so many numbers at each point as to make the arrangement impracticable. In the case of train service employes, the force is more or less mobile and to maintain an assigment by locations would require frequent changing of numbers for individuals, which is considered an objectionable feature.

A rule applying to all departments is that but one working number shall be assigned an employe during a pay period, which working number shall not be used by more than one employe during a calendar month. While it is desired, so far as possible, to have an employe retain the same working number indefinitely, changes have to be made when he is permanently transferred from one division or department to another, or when his point of employment is permanently changed.

In general, each department has forms of time return especially adapted to the requirement of that particular branch of the organization, but in some instances the same form is used by two or more departments.

In train service, the conductor returns the time for the train crew (conductor and trainmen), and the engineer returns the time for the engine crew (engineer and fireman or firemen), on forms with appropriate headings for the detail that is needed to determine wages due and statistical data required for the use of the management and for governmental purposes. The return made by the engineer also supplies information for train and locomotive mileage statistics.

Train service time and mileage returns are prepared for trips or calendar days, according to the character of the service performed, and are passed through channels to the office of the Division Superintendent for checking as to correctness. After being coded for machine accounting purposes, they are sent to the Auditor of Disbursements, who has charge of machine accounting work.

Time returns of the Maintenance of Way Department, except for supervisory and office forces, are made on a daily basis. The forms are designed for reporting time and description of work by gangs. Spaces are provided for entering after the name of each employe, the time on and off duty and the total time worked separately for regular time and for overtime. The time of station and yard service employes of the Transportation Department and of supervisory and office forces of all other departments is reported on a semi-monthly time return.

Another form of time return is used for dayworkers and pieceworkers employed in the Mechanical and Stores Departments. This form requires each employe to report his own time daily. The time claimed is ckecked with the time clock record appearing on the card or with the record of time on and off duty inserted by the foreman at points where time clocks or recorders are not supplied. On this form, the workman describes his employment and shows for each assignment the time consumed, divided between regular time and overtime. The pieceworker merely inscribes « piecework » on his card instead of giving a description of the work, as there are auxiliary forms for reporting the time and the production of pieceworkers. The record of time worked as reflected by the daily time card is completely accounted for on a piecework slip which is prepared by the piecework inspector.

In the Car Department, payment for production is made only upon completion of work on a unit of equipment upon which the employe or gang has been engaged, hence the necessity for a provision to accumulate unfinished time until the work has been completed. At the close of a pay period, unfinished time accumulated during the period is paid for at daywork rates and the payment thus made is deducted from the final allowance at production rates when the job is finally completed. At completion, a detail of finished time is prepared by the inspector on a form provided for the purpose. This detail shows the unit of equipment (car number) on which the work was done, the operations performed (number of pieces) described by schedule numbers, and titles and authorized price for each.

In other departments, the work is reported currently as performed; and, in case an operation has not been completed in a day, allowance is made for the completed fractional part. No provision is made on time return forms, except in the Car Department, for the carrying of unfinished time; otherwise, the several forms of piecework time return are essentially the same. They may carry the time of an individual or a number of individuals when working as a gang. In the latter case, earnings are divided between the workmen on a percentage basis agreed upon by members of the gang.

All forms of time return are designed to reflect complete information relating to payment of each employe and all other data required for the various analyses of labor items for accounting and statistical purpose. They contain spaces for enter-

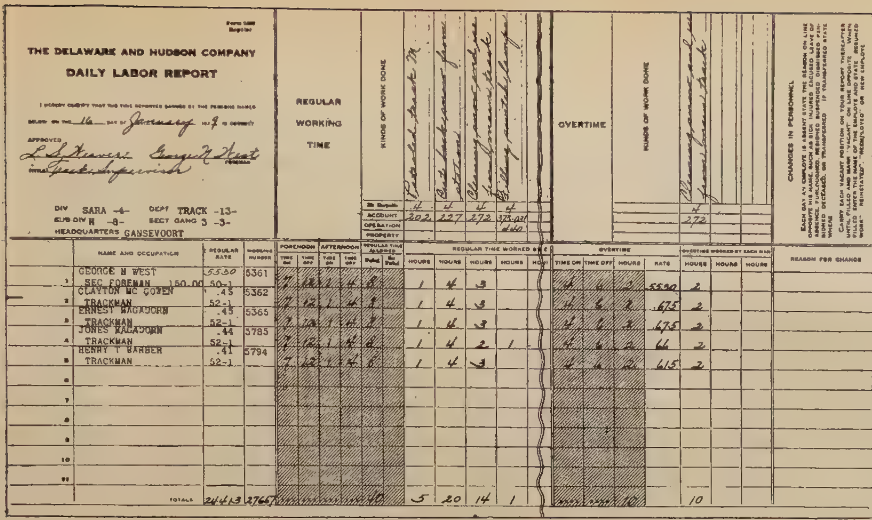


Fig. 5. — Daily labor report.

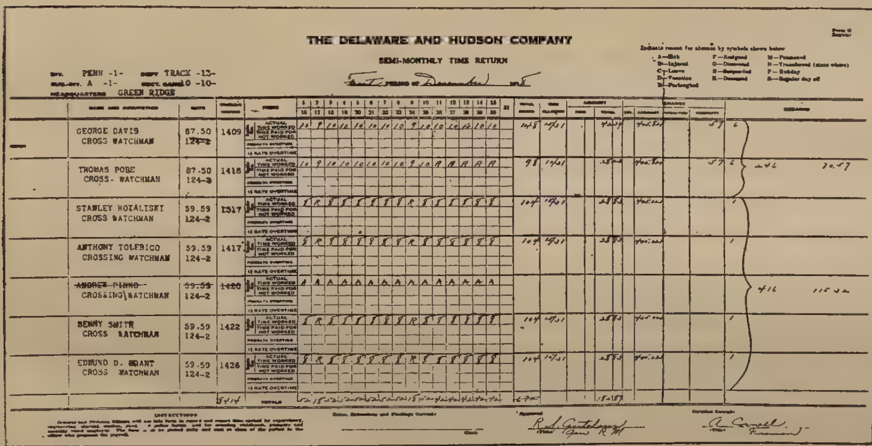


Fig. 6. — Semi-monthly time return.

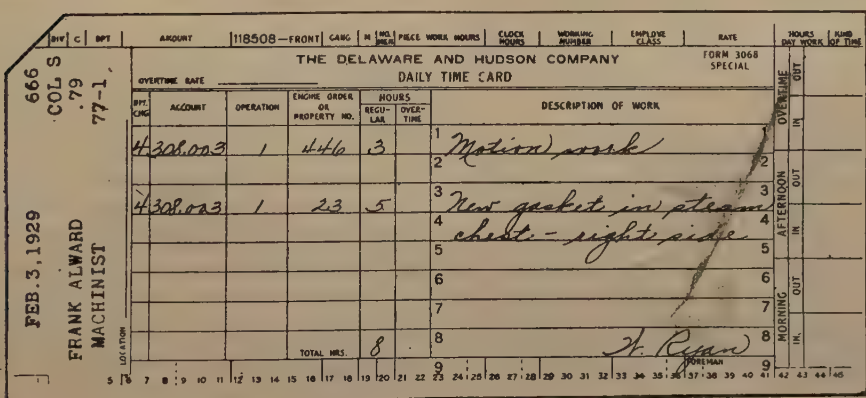


Fig. 7. — Daily time card.

ing codes used in machine accounting and also symbols for reporting absence of an employe from work due to illness, leave, suspension, or other causes.

All time returns (except those for general office and train service employes and auxiliary forms for piecework) are initially prepared in the office of the Auditor of Disbursements on an addressographing machine. Maintenance of Way Department daily time returns show division, department, gang, and location, followed by the personnel of the gang, there being shown for each employe, name, working number, title, rate of pay, and occupational classification. Returns thus prepared are sent to the various foremen for posting of time and description of work, about a ten days' supply being sent at a time. Changes in force occuring between the time of the initial preparation of the return and the time of its use are recorded by the foreman.

Daily time returns for the Mechanical and Stores Departments are similarly prepared, each card showing name of employe, working number, title, rate of pay, occupational classification, location, and date.

Semi-monthly time returns for all departments are prepared in advance and contain reference to division, department, gang, and location, followed by personnel, there being shown for each employe, name, working number, title, rate of pay, and occupational classification.

In the beginning, two addressographing machine plates were cut from master lists for each employe, one for use on time returns, and the other, showing only the name of the employe and his working number, for use on payrolls. These plates were then filed separately by location and gang. They have since been kept up-to-date by use of special forms submitted through channels for all authorized changes in positions, rates, and personnel.

Complete time returns (except for general office and train service), when properly approved by the officer in charge, are sent to the Division Accountant for checking and coding. He determines that no unauthorized changes have been made in force or rates, verifies the time claimed, and sees that sufficient description of the work is given for all accounting purposes.

Coding is accomplished exclusively by means of figures, a number inserted in a specific column serving as a symbol for a descriptive word or title. Code numbers are assigned to operating divisions or departments, locations, titles of accounts, and so forth, for example: Division 4, Department 23, Account, 308, Operation 2, Property 507, when decoded means Saratoga Division, Motive Power Department, Locomotive repairs, Classified repairs, and Locomotive No. 507.

An operator engaged in coding will, from constant practice, memorize many of these codes; otherwise, he must refer to the code book which is on file in every accounting office where needed.

Much of the coding of time returns is done en masse by use of follower forms or proof sheets which accompany the returns for a shop, enginehouse, station, or other unit of operation. Obviously, it would be unnecessary to code the division, department, and location on each individual slip, as that can be determined from the follower sheet, provided the returns of an individual unit are kept intact. Likewise, much of the information subsequently used, such as, working number, rate, and occupational classification, is placed on the time return when

initially prepared by the addressographing machine.

Coding by the Division Accountant consists, principally, of indicating the account. If the account requires further analysis as to the kind of work performed, the operation is also coded, for example : Work on automatic train control equipment attached to a locomotive, while chargeable to « Locomotive repairs », must be reported as a separate item, due to governmental requirements. To provide for this, Code 5 is assigned, which when used in conjunction with « Locomotive repairs » means « Repairs to automatic train control ».

Operation codes are extensively used for appropriation work to distinguish between capital account and operating expense charges.

Property codes are used for various purposes. When used in connection with equipment, generally the unit number (car or locomotive number) is also the property number. When used in connection with fixed property, code numbers are assigned to denote location, *i. e.*, station, bridge, or building, as may be necessary. For appropriation work, the appropriation number is used as the property code.

In the handling of time returns, the Division Accountant codes for such distribution as he requires for the proper handling of his accounts, knowing that the machines will return to him only such distributions as he has coded. The coded time returns are sent to the Auditor of Disbursements with a follower sheet attached to each set and accompanied by a transmittal list indicating the kind and number of returns forwarded and those still outstanding for the day or period.

Upon receipt of the time returns of the Mechanical and Stores Departments in the Auditor of Disbursements' office, a check is made against the transmittal list to determine actual receipt of those which have been reported as forwarded. The follower sheets accompanying the returns are used as a source of information for punching references which are common to all cards in the set, such as, division, department, gang, and date. They also serve later as proof sheets to verify the correctness of key punching.

PROOF SHEET

WAGE AND DISTRIBUTION CARDS

FIRST — SECOND PERIOD__________ __192__

______DIVISION______ GANG OR SUB-DIVISION______ DEPARTMENT

ITEM	INITIALS	DATE
Time Returns Checked and Coded		
Time Returns Reviewed		
Comptometer Footings		
Wage Cards Punched		
Distribution Cards Punched		
Distribution Cards Verified		
Tabulator Footings		
Cards Gang Punched		

ITEM	COMPTOMETER TOTALS	TABULATOR TOTALS	
		WAGE CARDS	DISTRIBUTION [illegible]
Rates			XXXXXXX
Working Numbers			XXXXXXX
Clock Hours			XXXXXXX
Number of Men			XXXXXXX
Amount of Piece Work	XXXXXXX		
Hours Day Work	XXXXXXX		
Hours Piece Work	XXXXXXX		

Fig. 8. — Proof sheet.

The returns are first handled in the Auditor of Disbursements' office by a general clerk who makes an examination to detect errors and to insure against omissions in the coding. Each set, with proof sheet securely attached, is then sent to a computing machine operator, where additions are made separately of

rates, working numbers, and hours. The totals of each are entered on the proof sheet for further reference. Returns are then routed to a key punch operator, where the various kinds of information required for determination of wages and their distribution to accounts are transcribed to cards designed for accounting by the punched hole method.

Three card forms are used for recording wages and distributions of wages in these departments. One of these is the card form previously described as serving the dual purpose of an employe's daily time card and a wage punch card, information relating to wages being key punched on the identical card used by the employe in reporting his time. The second form is a payroll card designed for condensation of wages and statistical information relating thereto for the entire period. This card is punched either from a semi-monthly time return or from a preliminary payroll, which will be described hereafter. The third form is used exclusively for wage distribution purposes.

Wage cards are key punched to indicate gang, working number, class of employe, hours worked, and kind of time (daywork or piecework divided between regular, overtime, constructive time, etc.). For dayworkers, the rate per hour and the number of hours of daywork are punched. For pieceworkers, piecework hours and wages earned on production basis for finished work only are punched. Unfinished time is accumulated until the work is completed.

Distribution cards are key punched to indicate gang, working number, division chargeable, operation, property, classification of employe, rate of pay for daywork time, account chargeable and whether applicable to freight, passenger, or common, piecework hours and money amount (finished time only), and kind of time. Distribution cards are reworked in a key punch verification machine to verify the original punching.

Wage and distribution cards, with proof sheet attached, then go to a tabulating machine where totals are extracted from the wage cards for rates, working numbers, hours worked, amount of piecework, daywork hours, and piecework hours. These totals are posted to the proof sheet and are balanced so far as they relate to computing machine totals which were previously mentioned as having been inserted on this record. The distribution cards are then run through the tabulating machine and the amount of piecework and total hours worked are posted to the proof sheet. These items are balanced with similar items produced by the tabulating machine from the wage cards. With these balances obtained, the key punching is presumed to be correct.

Wage and distribution cards are then sent to an electric duplicating punch where date of work, operating division, and department references are punched, this information being extracted from the proof sheet. Except as to money figures for daywork, wage and distribution cards have now been completely punched. As the cards punched for piecework are now complete, they are set aside. The other cards, which have been punched for daywork but still lack money figures, are held for accumulation in convenient quantities.

A file is maintained of master cards, peculiar in design to be distinguished from wage and distribution cards, and on which are punched hours and fractional parts in tenths from one-tenth to ten hours for each existing hourly rate

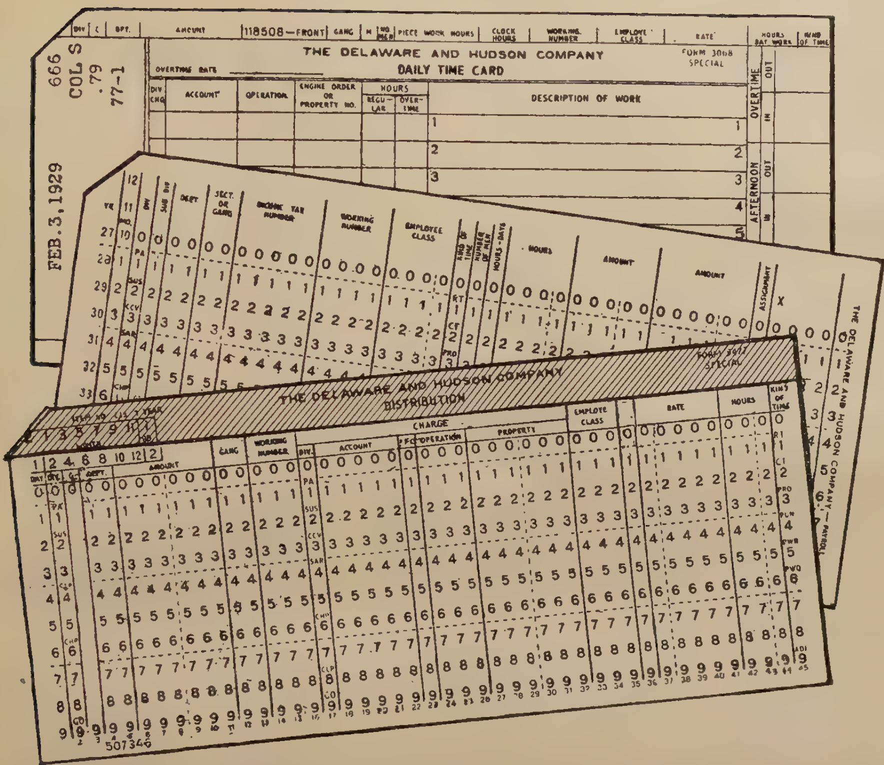


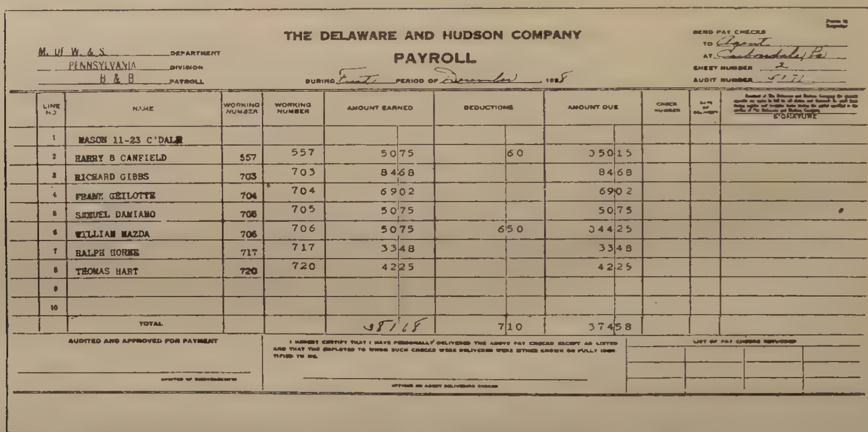
Fig. 9. — Payroll and labor distribution cards.

and the money extension. When an accumulation of wage and distribution cards is complete, the three forms, wage, distribution, and master cards, are sorted as to hours and rate for the purpose of matching all cards of like time and like rates. When this has been accomplished, the cards are taken to the electric duplicating punch, where, by means of a master card for each set, each wage and distribution card, as it passes through the duplicating machine, is punched to record the appropriate amount of money for the rate times the hours. Wage and distribution cards, including those for piecework which were set aside, are then sorted in order of division and department. Further sorting is made in order of gangs; and, as the gang reference appears in different fields on the two cards, this sorting automatically separates the wage and distribution cards into two groups.

The cards are then separately run through the tabulating machine for the purpose of balancing hours and money on the two kinds of cards. These figures are posted to a control sheet designed for the purpose, the cards being filed in the order named until the close of the payroll period. Upon receipt, the semi-monthly time returns of employes who are paid at monthly rates are examined as to correctness and coding and are

passed to a key punch operator who punches a payroll card for the wages of each employe during the entire period, this card carrying space for all of the information necessary for the preparation of payrolls and wage statistics . Distribution cards are punched from semi-monthly time returns in exactly the same manner as from the daily return previously described.

At the close of a pay period, wage cards are removed from files in division, department, and gang order and are further sorted by working numbers and in order of time and rate. Following this sorting, a preliminary payroll is prepared on blank paper by use of a tabulating and printing machine. This tabulation, when printed, shows for each working number, the gang reference, employe's classification, and by kinds of time, rate of pay, daywork hours, number of men (count as of a specific day of each month), total hours worked, piecework hours, money amount for each kind of time, and total. Subsequent to this tabulation, preliminary payrolls are adjusted to include amounts to be allowed



THE DELAWARE AND HUDSON COMPANY

PAYROLL

M. OF W. & S. DEPARTMENT
PENNSYLVANIA DIVISION
B & B PAYROLL

SEND PAY CHECKS TO Agent AT Carbondale, Pa.
SHEET NUMBER 2

LINE NO	NAME	WORKING NUMBER	WORKING NUMBER	AMOUNT EARNED	DEDUCTIONS	AMOUNT DUE	CHECK NUMBER		SIGNATURE
1	MASON 11-23 C'DALE								
2	HARRY B CANFIELD	557	557	50 75	60	350 15			
3	RICHARD GIBBS	703	703	84 68		84 68			
4	FRANK GEILOTTE	704	704	69 02		69 02			
5	SAMUEL DAMIANO	705	705	50 75		50 75			
6	WILLIAM MAZDA	706	706	50 75	6 50	344 25			
7	RALPH HORNE	717	717	33 48		33 48			
8	THOMAS HART	720	720	42 25		42 25			
9									
10									
	TOTAL			381 68	7 10	374 58			

AUDITED AND APPROVED FOR PAYMENT

Fig. 10. — Payroll.

pieceworkers on guarantee and such other adjustments as many be in order.

Payroll cards are then key punched from the preliminary payroll to reflect in condensed form the information that is necessary for preparation of payrolls and other statistics. Total hours and money from the preliminary payroll are posted to a control sheet and these figures must balance with those previously posted at the time wage and distribution cards were balanced. At this point, all payroll cards for employes whose time is returned daily are merged with those of employes whose time is carried on a semi-monthly form of return. These cards are further consolidated with those which have been punched for deductions for board, insurance, uniforms, etc.

The standard form of payroll reflects the name of the employe, working number, amount earned, deductions, and total amount to be paid. Space is provided for showing the working number for

each employe in two separate columns, the reason for which is later explained. The payroll is initially prepared on an addressograph machine which prints for each gang, the name and working number of each employe, generally arranged numerically in order of the working numbers. The remainder of the information on the payroll is inserted by a tabulating and printing machine which prints the working numbers opposite those which were inserted by the addressograph machine, and for each working number, the amount of money earned, deductions, if any, and amount to be paid.

The working number of each employe is repeated on the payroll for the purpose of guarding against crediting to the account of an employe the wages earned by another, through erroneous location of names. After the preparation of each payroll sheet, a sight check is made to see that the working numbers on each line agree.

A recapitulation of payrolls is made by hand and the totals of amounts earned and deductions are balanced with the control sheet. The payrolls are then ready for payment.

The timekeeping and payroll procedure in the office of the Auditor of Disbursements for Mechanical and Stores Departments, as previously explained, can also be applied to the Maintenance of Way and Structures Department and to station and yard service of the Transportation Department. There are special provisions for the handling of piecework in the Mechanical and Stores Departments which do not apply to the other departments, otherwise there is no difference in the development of payroll data for all departments.

Except for train service, the methods employed to obtain labor distribution are the same for all departments. Distributions are made of hours and money by accounts and subaccounts with a separation of all operating expense accounts as between freight, passenger, and common. Punched distribution card are filed by divisions and departments and in some instances by subdivisions or locations according to the requirement. They are then sorted by division chargeable, subaccount, freight, passenger, or common, and account. In this order, the cards are run through a tabulating and printing machine, the result being printed on a distribution sheet.

On the standard distribution sheet there are columns for account codes, subaccount, freight, passenger, or common, subdivision or gang, hours, and amounts. Accounts requiring further analysis than provided for on the standard distribution sheet are also reported on other forms in detail, according to the requirement.

By the use of codes, it is possible to analyze an account by showing the classification of each employe engaged, which is equivalent to the showing of his title, Accounts can be broken down by rates of pay, kind of time, whether daywork or piecework, regular or overtime, etc. Work performed may be described by operation codes which, perhaps, are used more extensively in analyzing distribution to accounts which require considerable detail. Through the use of property codes, it is possible to determine on what particular unit the work is performed, whether a unit of equipment, such as a locomotive or car, or fixed property, such as a building, bridge, or a location along the track.

Operation and property codes are permanently set aside for known items, but when there is a need for coding an operation or property not contemplated, tem-

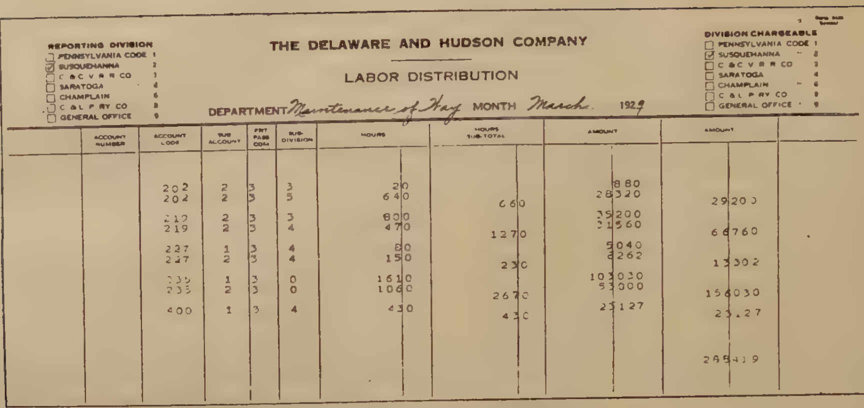


Fig. 11. — Labor distribution.

porary codes may be assigned by the Division Accountant; or, if a permanent code is desired, it can be obtained without delay.

The handling of timekeeping and labor distribution for train service employes by machines differs materially from other labor accounting. The time returns prepared by conductors and engineers go to yardmasters, enginehouse foremen, or others, and thence to the Division Superintendent, where a check is made by timekeepers who apply rates and also coding for distribution. These time returns are also audited in the office of the Auditor of Disbursements. Extension of rate by mileage allowance is made by computing machine.

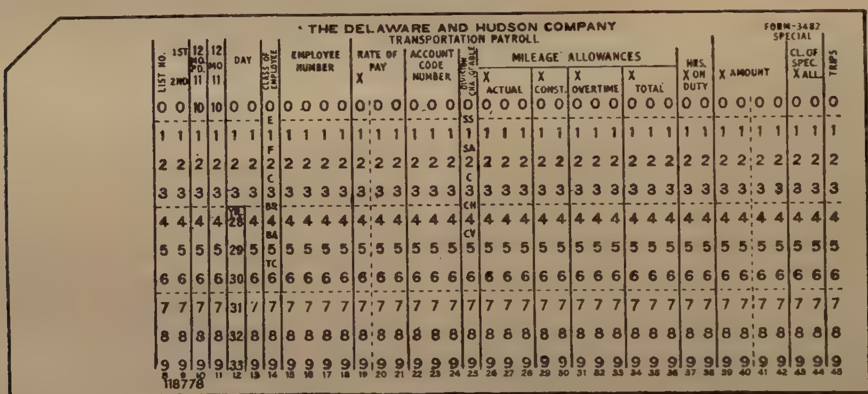


Fig. 12. — Transportation payroll card.

The payroll cards are then key punched to show date, class of employe, working number, account code, rate of pay, division chargeable, mileage allowances separated between actual, constructive, and overtime, total miles, money, number of trips, and classes of special service. Following this operation, the cards are run through a tabulating machine for the purpose of developing miles and money

PROOF SHEET.
TIME SLIPS AND CARDS.
ENGINE AND TRAIN SERVICE.

Division ....
Enginemen, Trainmen.
List Number..............
Month of............ 192...

ITEM.	Clerk's initials.	Date.	Rate.	Miles.	Amount.
Charges drawn from time slips					
Time slips counted					
Time slips audited					
Time slips extended					
Charge sheets extended					
Cards punched					
Cards checked					
Cards gang-punched					
Tabulation: miles, money, hours					
Money computed from slips					
Cards sorted by rates					
Tabulation and comparison					
Cards sorted by divisions					
Tabulation by divisions					
Cards sorted in pay-roll order					
Actual miles					
Constructive miles					
Overtime miles					
Deadhead miles					
Total miles					
Hours on duty					
Total money					

Div. No.	Miles.	Money.	Hours.

Totals.

Fig. 13. — Proof sheet.

for posting to a proof sheet. The total of actual, constructive, and overtime miles must agree with the total miles as a proof of the key punching. The cards with the time slips are then returned to a computing machine operator for addition of money, which must agree with total as reflected by the tabulator. A sorting is then made by rates and the cards are run through a tabulating and printing machine which prints the miles and money for each rate on the proof sheet. The proof sheet is then passed to a computing machine operator where extension is made of the total miles at each rate, which has the effect of providing a proof of the original computing machine extensions on the time returns.

Several times during each pay period, depending upon the number of time slips received, a sorting of the punch cards is made by divisional assignment. Cards so sorted are run through a tabulating machine and the miles and money developed are posted to a control sheet, which is balanced against the payrolls. At the close of the pay period, the punched payroll cards and cards which have been punched for deduction purposes (meal books, insurance, and other deductions) are sorted together by employe working numbers and are then ready for printing on the payroll form. At the proper time, payrolls are initially prepared by addressograph machine by insertion of names and working numbers. The sorted payroll and deduction cards are matched with the numbers appearing on the payroll to insure that the cards are in the same order as the corresponding numbers shown on the payroll. The payroll is then printed by a tabulating and printing machine, there being shown working number, deductions, and amount due for each employe, and total deductions and amount due for each sheet. These amounts are balanced with similar items already posted to a control sheet. As on payrolls for other departments, in this case also a sight check is made of the working numbers appearing in the two columns to avoid the possibility of crediting the wages of one employe to the account of another. A recapitulation of payrolls is made by hand and then the payrolls are ready for payment.

After completion of payrolls, the cards are sorted by division chargeable, employe classification, and account code for distribution of time and money. Tabulation is made separately for each division chargeable by class of employe, showing the account code, actual miles, overtime miles, total miles, hours, and amount for each account code, and the total figures are balanced with the control sheet. Various accounts, which require further distribution, are supported by detail sheets which are prepared by hand currently during the month from the original time returns.

APPENDIX *B*.

Compilation of freight commodity statistics.

The larger steam railway companies operating in the United States are required to render to the Government quarterly reports of freight commodity statistics showing the number of carloads and the number of net tons transported, and the

reporting carrier's gross revenue derived from revenue freight.

The report shows the number of carloads and net tons (2 000 lb.) under four classes : Revenue freight originating on respondent's road, terminating on line (local), and delivered to connecting carriers (interline forwarded); and revenue freight received from connecting carriers, terminating on line (interline received), and delivered to connecting carriers (interline intermediate); and in total; also the total freight revenue, subdivided into 156 commodity groups for carload traffic, and the number of tons and the amount of revenue for less than carload traffic.

Since accounts are kept on a monthly basis, the data for use in preparation of these quarterly reports are accumulated monthly by the use of punched cards.

The basic records from which freight commodity statistics are prepared are the waybills or the abstracts of waybills received at destinations on the reporting line and the abstracts of other carriers for traffic received by them from stations on or via the reporting carrier.

The first operation in accumulating data for freight commodity statistics is to transcribe the information from the waybills or the abstracts to cards by means of holes punched in the cards, code numbers indicating the stations, carriers, commodities, and class of traffic.

The weight and revenue punched in the card are verified by running the cards through the tabulating machine and obtaining totals for the weight and revenue. These totals are balanced with the totals shown on the abstracts, if for local traffic, and with the recapitulated totals of all of the abstracts, if interline.

When the punching of cards has been completed for the period covered by the report, the cards are sorted by use of the sorting machines into classes of traffic and commodities.

The cards for each class of traffic are then run through the tabulating machine separately and the number of cars and the weight and revenue obtained for each commodity under each class of traffic.

As the cards punched for revenue freight include some items of company material waybilled as revenue freight but entitled to free movement over the reporting carrier's line, deductions from the revenue freight totals are made for such items from tabulations made from cards punched from reports of company material freight bills.

In connection with freight traffic statistics rendered to the Government, it is necessary to report the number of ton-miles of non-revenue freight as well as those for revenue freight. The method by which the ton-miles are obtained is known as the digit method. This method saves an exceedingly large number of multiplications as compared with the old method of multiplying the weight by the mileage for each item. By the digit method, the multiplications are reduced to only nine operations by means of grouping the items of the same quantity.

The process is begun by punching cards for the individual waybills or groups of waybills as required, and the number of miles each shipment moved over the line punched in the original card, or these cards may be sorted and grouped into the order of the forwarding and receiving stations, or further sorted into commodity order if desired, and tabulations made by printing tabulating machine to obtain the total weight for all the traffic moving between each forwarding and each destination station.

The number of miles between each of

the stations listed is entered by hand on the printed record and additional cards are punched showing weight, miles, and such other additional information as will designate the class of traffic and make possible the location of the item if necessary.

The accuracy of the weight punched in the original cards and in those punched from the totals obtained from the tabulated totals may be verified by tabulating each set of cards.

The process of obtaining the ton-miles is begun by sorting all the cards in which the mileage has been punched as to digits in the unit position of the mileage figure. That is, all cards containing a cipher in the unit position of the mileage figure will be brought together and all those containing the digit « 1 » in the unit position will be brought together, and so on, up to and including the ninth digit.

The cards for digit « 1 » are then run

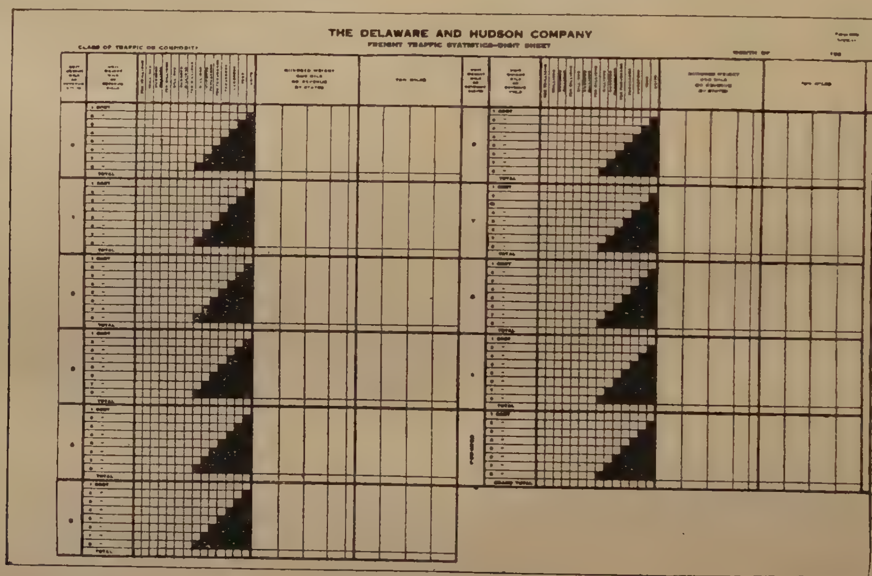


Fig. 14. — Digit sheet.

through the tabulating machine and a total of the weight obtained and entered on the digit sheet opposite digit « 1 », « 1 Sort ». The digit « 2 » cards are treated in a like manner, and the process continued until all of the nine digits for the first sorting have been tabulated.

All of the cards are then sorted again, this time for the digits in the « tens » position and again the cards for each digit, one to nine, are tabulated and the total weight for each obtained and entered on the digit sheet opposite the item marked « 2 Sort » for the appropriate digit.

For the third time the cards are sorted, this sorting being for the digits in the « hundreds » position, and the total weight for each digit is obtained by tabulations and the totals entered on the digit sheet opposite the appropriate digits on the line marked « 3 Sort ». Further sort-

ings are made in like manner as required. Each section is then totaled and the amount posted opposite « Total ».

The totals for each of the nine digits are multiplied by the amount of the digit and the product posted under « Hundred Weight One Mile » opposite the total of the section for each digit. The results of these nine multiplications are totaled and the sum entered opposite « Grand Total ». This total when divided by 200 gives the net ton-miles. It is necessary to divide by 200 for the reason that the cards are punched to show the weight in hundredweight and tenths thereof. A similar process may be followed in arriving at the ton-miles for any class of traffic and for any commodity.

APPENDIX C.

Machine station accounting plan.

A committee of the Railway Accounting Officers Association made a study of various plans of station accounting, such as, the zone plan of centralizing station accounts in one bureau, the machine plan, and other station accounting methods. The complete detailed procedure to be followed under the machine plan may be found on pages 139 to 145 of *Railway Accounting Procedure,* 1928 Edition, edited by E. R. Woodson, and published by the Railway Accounting Officers Association, Washington, D. C. In brief, the salient features of this plan are the following :

A separate card is punched for each accounting item for each consignment for accounting purposes. The following machines and equipment are necessary in addition to the usual equipment :

- Key punches;
- Seven unit printing tabulators;
- Card sorters;
- Filing cabinets for cards;
- Nonlisting machines.

The different accounts may be designated by code numbers; and, where desirable, further separation may be made and a separate code number used for each account, separating city from connecting line and issuing roads.

Cards are punched for each debit and credit item, which, after being balanced, are filed. When waybills are received, they are revised as to weight, rate extension, etc., and freight bills issued. Separate daily reports are made for local and interline waybills.

The weight, freight, advances, and prepaid columns of the report are totaled and the waybills coded. The waybills are then passed to key punch operators to punch card for the total net debit or net credit for each consignment. The following information is punched in the card :

- Month, day, year which represents date of reports;
- Account number;
- Waybill number;
- Month, day, year of waybill;
- Station;
- Waybilling road, if interline;
- Pro number;
- Debit (net) or
- Credit (net).

Cards are then passed to the tabulating machine operator and detailed tabulated statement prepared. The grand total of

amount of net debit is balanced with the freight, plus the advances less the prepaid charges as shown on the reports. Cards are filed in filing cabinets by code numbers and labeled « Not cleared ».

Shipping tickets and connecting line transfers received are rated, extended, and waybills prepared. The waybills are then abstracted, separate reports being made for local and interline waybills, and the reports are footed as to weight, freight, advances, and prepaid. Waybills carrying advances or prepaid are coded to show the following information :

Amount of debit for prepaid;
Amount of credit for advances;
Code number for station to, if local;
Code number for going off junction, if interline;
Code number for waybill destination road, if interline;
Account number.

Waybills are passed to key punch operator, who punches card for all shipments carrying advances or prepaid. The following information is punched in the card :

Month, day, year per report to auditor;
Account number;
Waybill number;
Station to, if local;
Going off junction, if interline;
Waybill destination road number, if interline;
Connecting line pro number on rebilled traffic;
Debit or prepaid;
Credit or advance;
Clearances.

The cards are then passed to the tabulating machine operator, who prepares a tabulated statement from the cards. The total debit and total credit shown on the tabulated statement are balanced with the total prepaid, and total advances shown on the report.

After the reports have been balanced, they are forwarded to the freight accounting officer. The cards on forwarded traffic are filed by accounts in filing cabinets and properly labeled as to « Account number » followed by the words « Not cleared ».

Bills covering switching, weighing, demurrage, storage, or other miscellaneous charges, are prepared on an accrual basis, except demurrage assessed under average agreement plan, which is covered by bill at the end of the month. These bills are coded and cards punched. Cards are tabulated in detail and the amounts as shown on the various bills checked against the tabulated statements to insure accuracy of the cards.

The total debits or credits as established for the day are posted in the cash book cpposite the proper date under proper account. The posting is done from the tabulated statement prepared by the printing tabulator.

All accounts not designated by waybill or freight bill numbers, such as relief claims or miscellaneous bills, show the identifying number on the card in space provided for waybill number.

As collections of inbound charges are made on city business, the date of the freight bill, freight bill number, and amount of collections are recorded on collection statement under caption « Inbound ». When settlement is received from connecting line, reference to the connecting line and to draft number and the amount is recorded on collection statement. Collections covering outbound prepaid charges are likewise entered on collection statement showing date of waybill, waybill number, and the amount under caption « Outbound ». If the pre-

paid outbound charges are collected before waybill has been issued, the cashier assigns a number to the shipping ticket from a series assigned for that purpose. Collections covering demurrage, storage, switching, etc., are entered on collection statement showing identifying information and the amounts under the proper captions.

All disbursements of cash made by the cashier are entered on disbursement statement showing identifying information and amounts under proper captions.

Totals for the various accounts shown on the collection or disbursement statements are carried to the cash summary statements and entered opposite proper items. The amount of cash on hand as shown on the cash statement is balanced with the actual cash on hand.

The cash collection statements with freight bills attached are passed to file clerk, who withdraws from the files labeled « Not cleared » cards covering items as entered on the collection statement, after which the cards are tabulated in detail. The total of the tabulated statement is balanced with the total of the amount shown on cashier's collection statement.

In order to show clearance, the cards covering the actual collections are punched to show month, day, and year according to the cashier's cash summary statement, and account number, and the cards are tabulated in detail. The total of this tabulation must likewise balance with the collections as shown on the cashier's cash summary statement.

When an amount covering outbound prepaid charges for which the waybill has not been issued is reported on a collection statement, a card is punched giving reference in the column headed « Pro number » to the number assigned to the shipping ticket by the cashier. When the waybill covering the outbound prepaid is issued, the serial number used by the cashier is likewise punched in the card under the caption « Pro number » and is matched with the card covering the prepaid charges paid, not billed, and both cards cleared from the account.

Periodical reports covering demurrage, storage, switching, relief claims, and all other miscellaneous accounts are balanced with the grand total of the cash book for each of these accounts.

Totals in the station cash book are accumulated daily and at the end of the month it is only necessary to add the totals for the last day's business to the accumulated totals, after which the totals for the month are carried to the balance sheet.

Cards not withdrawn from « Not cleared » files represent uncollected charges. These cards are tabulated in duplicate, the original statement being attached to the balance sheet in support of the amount entered thereon as uncollected.

Immediately after the close of the month's business, all cards covering items that have been cleared from the accounts are sorted, each account separately in pro number order on the received side, waybill number order on the forwarded side. No separation in the accounts on the inbound and outbound business is made as between city and the various connecting line accounts. After the cards have been properly sorted, tabulated statements are prepared and bound for record purposes.

The foregoing plan can be adapted to any style of card and printing tabulating machines. It is also possible to extend this plan to include all details in connection with the zone plan of station accounting.

[625 .143.2 & 625 .143.3]

The heat treatment of rails in service.

The war against corrugated wear,

By Edmond MARCOTTE,

PRIZE MEDALLIST OF THE INSTITUT DE FRANCE, PROFESSOR AT THE ECOLE DES TRAVAUX PUBLICS

Figs. 1 and 2, pp. 541 and 542.

(*Le Génie Civil.*)

The wear of rails. — The excessive wear on certain sections of tramway lines, is a matter which causes the operators much anxiety. The papers read before the General Technical Meeting of the *Union des Voies ferrées et des Transports automobiles* (Light Railways and Motor Transport Companies Association) reflected this feeling. Much interesting information on the subject will be found, especially in the report presented at the IVth General Meeting, by Mr. Gros, Chief Civil Engineer of the *Société des Transports en Commun de la Région Parisienne* (S. T. C. R. P.).

Wear, due to rubbing, grinding, slipping, shocks, and vibrations, increases very rapidly with the weight and speed of the vehicles, the frequency of stops, and the rate of acceleration, negative when stopping, and positive when starting. The wear of rails grows in this way, and to an annoying extent, in those parts of the system carrying an intense traffic.

In addition, — especially on curves, or gradients — the wear of the running surface shows itself in the form of undulations, or corrugations, at first very small, but which soon become very evident, and soon cause the rolling stock, and the formation, to be subjected to destructive vibrations (1).

Refacing the running surface by mechanical means. — When the corrugated wear appears on short length sections, the grinding arrangement devised by Mr. Gros can be used.

A triangular guide can be set by means of a screw, so that the grinding wheel can move in parallel with the surface to be ground. In this way, 2 to 7 m. (6 1/2 to 23 feet) of manganese steel rails, can be levelled off per day, 2 to 3 mm. (0.079 to 0.118 inch) being removed. There are also other devices of the same kind.

When the corrugations extend over a considerable length, a plant of greater capacity must be used. The S. T. C. R. P. use a lorry 2.50 m. (8 ft. 2 1/2 in.) long, the chassis of which is fitted with four planes each with ten blades of special « triple express B » steel, which are set to the correct cutting angle. The necessary pressure on the planes is provided

(1) The corrugated wear of rails, has been investigated by Mr. Ch. Frémont in the *Génie Civil* of the 13 November 1926, vol. LXXXIX, No. 20, p. 425 and of the 1 October 1927, vol. XCI, No. 14, p. 326. See also the *Bulletin of the Railway Congress*, April 1928, p. 275.

by a counter-weighted lever, and cutting is facilitated by using plenty of water. This tackle is hauled by a motor, which can travel at a steady speed of 4 km. (2.5 miles) an hour, in both directions, when the work is being done.

On the average 180 m. (197 yards) of single line, can be planed during a night : the output naturally depends upon the hardness of the steel, and the depth of the corrugations, which can not be removed in a single cut in all cases.

Various types of planing machines have been designed.

Mr. Bacqueyrisse, General Manager of the S. T. C. R. P., when taking part in the discussion on Mr. Gros's paper, stated that he thought the best machine was the one that was also the simplest. The machine just briefly described, uses bogies all companies possess: all that is needed, is to fit to them planes which are readily made, the cost of the machine being also very low.

Effectiveness of planing. — The period during which the track, after planing, remains in good order, provided the operating conditions remain unchanged, does not depend only upon the quality of the rail itself. For example, if the rail is one that does not normally show corrugated wear, and if the corrugations are due to accidental causes, the corrugated wear will not recur. A defective joint can start corrugated wear on the two rails, but if the rails are planed after the defective joint has been repaired, the corrugated wear will not reappear.

The removal of corrugated wear by planing is therefore good practice, since, if it is not done at once, the track will soon become unusable. None the less, planing is not a general and certain cure. It is therefore necessary to find some more thorough remedy than planing.

If the joints can be maintained in good order, it is hardly possible to suppress the up and down gradients and curves, nor the oscillations of the rolling stock, nor alter the traffic or number of stops. It is therefore on the rails alone that action can be taken.

Sorbitic structure. — We have already dealt with the question of the surface hardening of new rails, when being rolled by the C. P. Sandberg process in use at the Hagondange Works, and now being installed at the Micheville Steel Works (1).

This process gives the rail a sorbitic structure. It is of value, not only against ordinary or corrugated wear, but also against the breakage of rails laid on sleepers and subjected to bending, because this structure is the one most suitable for hindering superficial fissuration from extending into the inside of the rail. This has been proved by many experiments on a large scale, in America and in England.

Further tests under difficult conditions, have been taken in hand in France, to see to what extent this improvement is maintained under the effects of frequently repeated slipping. This struggle to overcome the accidental breaking of rails, is of importance to the railway companies, because accidents resulting from the fracture of a rail are often of a very serious character.

Treatment of rails in position. — In the case of tramway rails in use, laid

Fig. 1. — Macrograph of a rail treated *in situ*. (The dark lenticular part indicates the hardened zone.)

in the roadway and consequently very costly to renew, the same inventors have suggested a method of treatment which

(1) See the *Génie Civil* of the 22 October 1927, Vol. XCI, nº 17, p. 411.

Fig. 2. — Macrograph of a rail treated *in situ* (35 magnifications).

(Transition zone between the martensitic and the ordinary structure of the rail).

consists in heating the middle part of the running surface, by means of the oxyacetylene flame, and subsequently cooling down the rail with a jet of water. The necessary equipment is fitted on a trolley which can be so arranged, that the burners are moved forward at a predetermined rate. In this way, it is possible to obtain the hardest structure known, namely, the *martensitic*.

The conditions of heating, the type of burner, its capacity, the quantity of cooling water, the speed of movement of the burner, are all known very exactly, as the result of many tests, carried out on more than 1 000 km. (620 miles) of line.

In practice, the ordinary structure of the running surface of the rali, can be definitely changed to perfectly hard and wear resisting martensite (fig. 1) to a depth of 5 to 6 mm. (3/16 to 1/4 inch).

Between the martensitic layer and the part of the rail unaffected by the heat treatment, there are layers gradually decreasing in hardness from that of martensite to that of the ordinary steel.

Underneath the martensitic layer will be found in consequence, the following layers (fig. 2) :

- troostite martensite,
- sorbite,
- sorbite ferrite,
- the ordinary mixture of ferrite and pearlite.

The gradation in depth of the different structures is the best one can obtain. Certain people, however, think it would be of greater value to endeavour to get the sorbitic structure alone (as is done in the case of new rails treated at the works) instead of the martensitic. Obviously by moderating the cooling off, as for example by setting the jet of water further from the burner, it is possible to obtain the sorbitic structure to a depth of 5 to 6 mm. (3/16 to 1/4 inch) or more; but in this event, the surface structure under micrographic examination shows the presence of troosite embedded

in a martensitic matrix; this is not the way to get the full hardness that can only be obtained from the pure martensitic structure.

Everything, therefore, should be done to avoid any action liable to moderate the cooling off to any appreciable extent, except as we shall see further for high carbon rails.

Mechanical characteristics of the treated rails. — The following is a summary of the observations recorded in various test houses :

1. Under a load of 50 t. (49.2 English tons) a 19 mm. (3/4 inch) Brinell ball leaves no appreciable impression on the running surface.

2. The normal hardness of the hardened layer is expressed by the number 500 for the Brinell standard test; the hardness varies naturally with the carbon content of the treated rails.

3. The macrographic and micrographic examinations of sections of treated rails, show there is no appreciable line of demarkation between the different layers of the metal, the change of structure being gradually merged into the original structure through the intermediate structures.

4. The shock or drop tests, reveal remarkable adhesion between the treated zone and the rest of the rail.

5. If an attempt be made to chip the rail with a chisel and a 1 1/2 kgr. (3.3 lb.) hammer, the rail is hardly marked; the metal is neither broken nor even nicked.

6. Furthermore, test pieces cut out from different depths, show that the treatment, when correctly applied, can prevent existing fissuration from developing.

Description of the equipment. — The equipment used when carrying out the treatment, consists of an acetylene generator, six oxygen cylinders, and a water tank mounted on a trolley, which can be driven forward at slow speed and which carries in front of it, and near to the rail, the gear for heating (an oxy-acetylene burner) and for cooling off (water jet).

It would be possible to treat two rails at the same time, but as the forward rate of movement of the burner varies according to circumstances (it is controlled by the appearance of the rail after it has been heated), it is better to treat only one rail at a time.

For the same reason, it does not appear practicable to arrange for the forward movement of the trolley to be controlled automatically. It would not be impossible, however, to combine a pyrometer placed close up to the rail, with a differential control of the forward movement of the burner, and thereby be able to use several burners at the same time, with a corresponding reduction in cost.

The acetylene generator is of the ordinary commercial type with a capacity of 5 m^3 (177 cubic feet) per hour; the oxygen cylinders are of the usual pattern; they are coupled together in two batteries and connected to the burner in such a way, that when changing from one battery to the other, there is no interruption in the flame. The burner used is the British Oxygen Company's pattern, with twin jets working at a pressure of about 3 hectopiezes.

To prevent the regulators freezing through the high degree of expansion of the oxygen, they are surrounded by a water jacket heated by radiation from the flame of the burner.

The amount of water used to cool off the rail and to protect the road paving by means of lateral jets from perforated tubes, is about 4 m^3 (880 gallons) per night (five and a half hours work).

The work is done at night in order to avoid the interruptions which would adversely affect the regularity of the treatment. The forward speed depends upon the quality of the rail steel, and the me-

teorological circumstances when the work is being done. Normally 8 to 9 m. (26 to 30 feet) of rails per hour, are treated, that is to say, about 220 m. (722 feet) a week when using one trolley.

Carrying out and checking the work. — The forward movement of the trolley should be under the control of an experienced operator : the education of this workman takes little time, but he must be thoroughly conscientious, so that he can be relied upon to so regulate the movement that he always gets the same appearance and the same heat, according to the different qualities of steel, the atmospheric temperature, and the fluctuations in the output and pressure from the acetylene generator.

As we noted earlier on, the operation cannot be regulated automatically. The work can, however, be checked by means of a scleroscope, such as the small portable pattern using a ball.

Special burners are available for use under exceptional conditions, such as on curves, but the jets are usually 14.3 mm. (9/16 inch) in diameter.

The cones which direct the gaseous jets are set almost in contact with the rails. Below them, orange red discs, which are almost melting, will be seen to appear. From this point the only thing the operator has to take care of, is to propel the trolley forward as quickly as possible, *so long as the coloured band* so formed (which he watches through smoked glasses), *remains the same colour, and the same width.*

The workman should be paid a premium depending upon the uniformity with which the work is done. Treating the rails *in situ,* is essentially a day work job, and railway companies which have confided the work to a contractor at a price per linear metre, have not always been entirely satisfied with the result.

Preliminary investigations. — Although the conditions under which the treatment should be carried out are perfectly known, and although it is always possible to certify that a treated zone of an uniform width, depth, and hardness, will be obtained, it is always as well before starting to treat a large number of rails, to analyse the metal and to make a few tests on samples from the line to be treated and hardened. It will sometimes result in the position and especially the spacing of the jets being altered, as well as the cooling off and the speed of movement of the trolley. It is of course most instructive when the preliminary trials are carried out on the track itself.

It is unnecessary to repeat that the planing of the rails beforehand is essential. A note should be made of all unsatisfactory places such as folds in the metal, corrugations and other defects in the track and joints, so as to treat only perfectly sound rails. The greater part of the defective results, are due to a lack of care when examining the track prior to treatment. On the other hand, the purity of the acetylene is unimportant, so that there is no need to use dissolved acetylene, the use of which would increase the cost.

RESULTS OF THE TREATMENT « IN SITU ». — *Resistance to ordinary wear.* — When the wear after, and prior to treatment, is compared, the traffic has generally appreciably increased, so that the true saving due to the process is greater than that actually recorded.

The average of the results obtained on the Bath, Birkenhead, Blackpool, Bolton, Bristol, Bury, Cardiff, Derby, Edinburgh, Glasgow, Hastings, Leeds, Liverpool, Manchester, London Metropolitan, Newcastle, Preston, Reading, Sheffield, South Shields, Swansea, Wallasey and York tramways, shows that the wear of treated rails, is less than half what it was previously under less difficult conditions.

It has been calculated, in England, that 2 777 000 vehicles can run over a treated line before wearing away the

4.8 mm. (3/16 inch) layer the structure of which has been altered by treatment. On the London, Liverpool, Leeds, and Manchester systems, where the traffic is heavy, and where the many stops on heavy gradients necessitate heavy braking, the number of vehicles passing before the layer hardened by the treatment is worn off, is as high as 2 146 000.

Action of certain brakes. — In certain parts of London, however, on the County Council Tramways and on the Metropolitan Tramways, vehicles weighing 20 tons running at 32 km. (20 miles) per hour have to be stopped quickly. The rails at these places last barely four years, and some have to be renewed at the end of two years. The treatment *in situ* can not be used, because it is destroyed by the temperature rising — in the rail and the brake shoe — above the critical temperature of the change of structure.

Transverse fissures are found — rather closer together on the rail than on the brake blocks — fissures, obviously the result of a series of starts and slips, which bring the surfaces up to a dull red heat, attach them together momentarily, then cause slip of the fibres of the metal which has become more malleable through heating, each surface affecting the other.

Resistance to corrugated wear. — The resistance of treated rails to corrugation, has been attested by many reports from British technical experts, who have examined treated sections of great length: 82 miles at Leeds, 52 at Liverpool, 83 at Manchester, etc.: We will report only the most characteristic examples.

On 300 m. (328 yards) of line on curve (*Victoria Embankment* at London) the corrugations had to be planed off twice yearly: the Sandberg treatment was applied to the rails *in situ* leaving witness rails untreated. This test was followed up during a number of years. After the passage of 3 240 000 vehicles, the treated rails showed no trace of corrugated wear, whereas the others were on the point of being renewed for the third time.

Another test on the same system (*London County Council*) gave the same results. If on some tramway systems, corrugation appears at certain places in treated rails, it is always after a very long time, and only on rails which, owing to their low carbon content, cannot be hardened sufficiently. Furthermore, the length on which corrugation appears is always insignificant in comparison with that on which this type of wear appeared before treatment.

Adhesion on treated rails. — Some engineers consider that the increased hardness may reduce the adhesion. Mr C. J. Spencer, General Manager of the Metropolitan Electric Tramways of London, carried out some tests which showed that the treatment in place has no appreciable affect on the adhesion. Certain atmospheric conditions make the braking difficult; dirt from the roadway may also cause slipping, but this occurs with all rails, treated or not.

Flaking. — On more than 1 000 km. (620 miles) treated, belonging to 42 different systems, only about a thousand metres (1 094 yards) have shown any tendency to flaking.

Although this defect only affects 1/1000 of the rails treated, it is sufficiently serious to be looked into.

Naturally the flaking can be electrically welded, but it would be better to prevent it occuring. Each time flaking has occurred, a careful investigation has resulted in the causes being ascertained. The two principal are:

a) *Break of continuity in the metal* through *segregation*, inclusions, internal cracks, and other defects;

b) *Excessive carbon content.*

Due to these causes, the following factors may aggravate the effects;

c) *Defective contact* between wheel and rail, the effort transmitted being concentrated at a point becomes much more intense;

d) *Excessive* treatment of rails *with high carbon content.*

It is dificult to guard against internal defects, but the careful examination of the surface reveals all the defects affecting it, and which are, moreover, the most serious.

As for the carbon content, this is never a reason for not treating the rail : it is only necessary to modify the cooling off to suit.

The specific gravity of the martensite developed by the treatment increases with the carbon content: a high carbon rail will thereby acquire a high degree of hardness, and there is no use in treating it like a mild steel rail.

The result of the various observations recorded on the different systems is that:

1. Nearly all the rails showing flaking were high carbon rails of not less than 0.75 % carbon.

2. When rails of lower carbon content show flaking, it is due to defects that should have been seen had the inspection of the rails been done carefully.

The investigations made by Mr. R. B. Holt, Engineer of the Leeds tramways, have shown that there is a limiting carbon content above which the treatment must be modified if the sudden cooling off is not to engender small internal cracks which will quickly develop.

It was therefore decided to give up the practice of treating all rails as thoroughly as possible. Since 1924-1925 as a result, the thermic treatment of lines laid with rails similar to those which showed signs of flaking, has not been followed by any such flaking.

Thus at Toronto, the use of low pressure apparatus has prevented — and entirely — since 1924 the formation of flaking which had caused the tramway company much anxiety. Flaking similar to that noted at Toronto, showed itself at Glasgow after the thorough heat treatment of American rails of the same composition; the causes and their effects being identical in the two cases, the same remedy produced the same satisfactory cure.

Broken rails and fractured joints. — At Bournemouth, the breakage of certain rails was ascribed to this treatment. They occured on a section treated during a violent storm which interrupted the work frequently; each time the trolley rolled back a little so that when the work was resumed, a part already treated was again dealt with.

This incident brought to notice the drawbacks of having to restart the work and the present practice is to leave a short gap between two parts treated in turn.

In the early days, the treatment tended to remove the edges of the fish plated joints; this is avoided either by lifting the burners when passing over the joints, or by protecting the joints with clay.

In the case of welded joints, the treatment *in situ,* can only do damage if the welds have been badly done, or are only surface welds : high carbon steels can only be welded with difficulty whatever process be used, and it is necessary when it is desired to treat such rails, to prevent any movement at the joints, and also to protect them by clay pads.

Protection of road paving and surface. — There need be no fear of doing any damage to the road way; the edges near the rail should be protected by jets of water distributed through perforated tubes placed at the side of the burners. This method satisfactorily protects roadways whether paved (granite, sandstone, or wood), asphalted, concreted or

of tarmacadam, and in general of any kind of surfacing.

The cooling by water is sufficient to ensure that at 30 cm. (11 13/16 inches) behind the burner, the temperature does not exceed 32° C. (89.6° F.) this temperature falling to 21° C. at 1.50 m. distance (69.8° F. at 4 ft. 11 in.) Micrometer measuring instruments inserted in the roadway or in the paving in the neighbourhood of the part under treatment, have in no instance recorded any movement.

Depth of treatment. — The efficacy of the treatment extends to the martensitic zone formed, 4 to 5 mm. (5/32 to 3/16 inch) in depth, below which the hardness diminishes gradually as we have said.

When the wear has removed the larger part of the martensitic layer there was some fear of serious defects appearing, such as the wheels running on surfaces of varying hardness. In practice the depth of the martensitic zone and the transition zones below it is very uniform as has been proved from sections cut out of rails at many points, and examined macrographically and for Brinell hardness.

Repeated treatment. The treatment *in situ* can be applied, after the martensitic zone has disappeared, a second, and even a third time. This has been done at Leeds, Manchester, and Croydon, on considerable lengths carrying heavy traffic. Naturally it can only be done provided the rails when first treated, are not too far worn.

It is easy to calculate the benefit there would be if rails in sections, where the traffic is heavy, were treated when new. It would also be possible to deal with low carbon rails, and thereby prevent the loss of metal which occurs during the first year in service, a loss which often reduces by 4 mm. (5/32 inch), the vertical distance between the running surface of the rail and the groove, shortening thereby — and appreciably — the total life to be expected from the rail.

Conclusion. — The Sandberg treatment *in situ*, based on a very simple fact, has met many obstacles in its applications that have been overcome, thanks to the investigations of the inventors, and to the assistance of the Engineers of the tramway companies; the latter having appreciated the benefits to be obtained from the treatment, were very anxious that the few detail defects should be overcome.

The reduction in the general wear, the suppression of the corrugated wear, and the avoidance of too early renewal of the rails, with the corresponding disturbance of the roadway, can result in quite appreciable economies. The purchase of sorbitic rails on the one hand, and on the other the generalisation of the martensitic treatment *in situ*, should therefore be encouraged.

As regards the treatment *in situ*, for the tramway companies, it is a question of economy, without any danger, as much experience on over 1 000 km. (620 miles) of line has more than amply proved.

As for the sorbitic rails, for the tramway companies it is an economy, and it also gives greater safety. The tyres of the wheels themselves, can also be sorbitic; many thousands of such sorbitic tyres are in use on the railways of Great Britain.

[62. (01 & 669. 1]

The relative values of the tests employed during the inspection of steel for manufacturing purposes, [1]

By R. GRANJON,

MANAGER OF THE CENTRAL OFFICE OF THE AUTOGENOUS WELDING ASSOCIATION, PARIS.

Figs. 1 and 2, pp. 549 and 550.

Under this title, we reproduced in the February 1929 number an article by Mr. Ch. Frémont, published in the Génie Civil. *This article resulted in the publication in the same paper of a note which impartiality commands us to bring to our readers' notice.*

(The Editor.)

Mr. Ch. Frémont published in the *Génie Civil* of the 24 March 1928 (2) an article in which he cited and discussed the article published over our signature in the *Bulletin de la Société d'Encouragement pour l'Industrie nationale,* of July-August-September 1927, under the title « Autogeneous welding together of parts requiring special care ». Furthermore Mr. Ch. Frémont made and cut up for his demonstration, a spherical vessel in welded plate which burst through the original plate under hydraulic pressure carried up to rupture.

We have the right and the duty to refute any matter we consider to be wrong, and to endeavour to restore the confidence of the readers of the *Génie Civil* in autogeneous welding.

Mr. Frémont quotes certain phrases from our article and in particular one of our conclusions which he states to be *absolutely erroneous.*

Autogeneous welding, we said, can give an assembly of parts absolutely perfect having a strength comparable with that which would be obtained if the same piece had been entirely forged, drawn, or pressed.

And, as it was a question of static tests under hydraulic pressure up to bursting point, our contradictor remarks that such tests give no information as to the resiliency of the vessel tested.

We will simply remark that, in the tests in question required by the « Conseil d'Hygiène de la Seine » (the Board of Health for the Seine department) under the circumstances reported, the static test under hydraulic pressure was the only one to be used as it was a question of seeing how cylinders full of compressed or liquified gasses built up by autogeneous welding would behave if the internal pressures to which they are usually subjected were steadily increased as a result of rising temperature up to and inclusive of that due to the building in which they were stored being on fire.

The « Conseil d'Hygiène du Département de la Seine » had therefore correctly selected the conditions by subjecting gas cylinders selected haphazardly to excess pressure tests up to bursting

(1) This note has been submitted to Mr. Ch. Frémont who states he does not wish to modify anything he wrote in his article. (Note of the Editor of the *Génie Civil.*)

(2) See *Bulletin of the Railway Congress*, February 1929 number, p. 168.

(which occurred outside the welds) tests which are not so *anodyne* as Mr. Frémont was good enough to say, *when they are carried up to bursting* which is in no way the case in the tests of boilers, etc., carried out by the Service des Mines, wherein the elastic limit is never reached.

Let us now consider the resiliency tests Mr. Frémont considers so important and to which we too attach the greatest weight, when it is a question of investigating brittleness.

An autogeneous weld properly carried out with the usual materials used in the trade, will have the resiliency of the metal *as melted,* from which it is made. We said in the article (from which only certain lines were quoted) that the general or particular mechanical properties of such an assembly can be improved so as to make those of the weld equal to those of the adjacent metal, by adding to the applied metal suitable elements : manganese, nickel, vanadium, molybdenum, etc.

Let us ignore this practice although it is well established, and let us suppose we are dealing with mild Martin steel plates welded with Swedish iron or special mild steel rods, as is the general practice.

The resiliency of the resulting weld will be that of the metal as melted, that is to say more than good enough to stand the stresses, even if very abnormal and repeated, to which it may be subjected if care has been taken to see its position is suitably selected to ensure its working under reasonable conditions.

Mr. Frémont was right in wishing to ascertain the resiliency of the welds : unfortunately, he appears to have been curiously deceived in the selection of his materials.

I took, he said, a sphere of steel plate formed of pieces autogeneously welded together which had burst through the original metal under hydraulic pressure test carried up to fracture.

He then gave a photograph of the said sphere (fig. 1) which we know well, seeing we made it. But what our critic

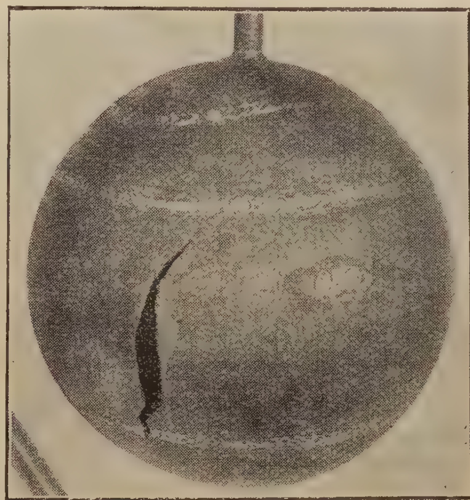


Fig. 1. — 9 7/8 inch diameter sphere made of steel plate, 5/64 inch thick, welded autogeneously.

undoubtedly did not know, was that this sphere was not spherical at first : it was indeed built up of « pieces joined together by autogeneous welding » but in the form of a cylinder : the sphere was only the result of the test under pressure carried up to fracture (through the plate itself) at 110 kgr. per cm² (1 564 lb. per square inch).

The photograph (fig. 2) shows at the centre the parts of the vessel, to the left, the welded cylinder [height 210 mm. (8 1/4 inches), diameter 215 mm. (8 1/2 inches), thickness of the plate 2 mm. (5/64 inch)] and to the right, the sphere obtained under hydraulic pressure, which is the one Mr. Frémont used, or one identically like it.

Let us allow that this static test demonstrates nothing...

But the test of resiliency by shock,

Fig. 2. — In the centre, the parts to be welded; to the left, the welded vessel; to the right, the same become spherical under a hydraulic pressure of 110 kgr. per cm^2 (1 564 lb. per square inch).

carried out on the welds of this same sphere which had been subjected to considerable stresses and the metal of which was fatigued and stressed to the maximum extent, could not be correct. These conditions obviously render valueless all the tests made by Mr. Frémont and described with complacency in his article in order to arrive at the conclusion that autogeneous welding can be the cause of serious accidents.

It is true all the plates are fragile and all the welds too; it is a question of degree, very useful to determine, but which one should take care to arrive at under suitable conditions.

With his characteristic enthusiasm and honesty, he wished to throw light on his beliefs about the resiliency of welds which a static test had left intact; he committed a mistake about the origin of the sphere which came into his possession, and he will be the first to admit it.

We have a further reproach to make to him, that is with regard to the test piece he reproduced in figure 4 of his article; we can hardly be expected to agree that the shock test of an autogeneous weld should be made on a test piece of a greater thickness, or with globules of melted metal, at the middle of the joint, which gives rise to resistance at this point and results in a fracture started in the angle as in the case of a notched bar.

We have often regretted that Mr. Frémont in his various investigations on the strength of units assembled by welding, should take as standards, welds deplorably badly made; we are at his disposal to have welds made in his presence by professional welders, who may be selected haphazardly by him if he wish.

He will then be able to carry out such trials and tests as he wishes and we shall be delighted if he will comment thereon for the benefit of the readers of the *Génie Civil.*

[656 .254 (.73)]

Highway crossing protection. (1)

Figs. 1 to 16, pp. 552 to 563.

History, theory and practice.

In the day of horse-drawn vehicles, adequate protection at higway crossings was afforded by placing conspicuous signs at the crossing, one sign generally sufficing for a single or double-track crossing, the lettering on the sign conforming with the ideas of various railroad officials, State laws or State authorities. It was required that the engine whistle be sounded at varying distances from the crossing — 1/4 mile being the most favored; the engine bell to ring until the train reached the crossing.

The speed of horse-drawn vehicles was such that to avoid arriving at the crossing at the same time as the train, they had to be quite close in order to hear either the engine whistle or the bell when the train was 1/4 mile away. Further, the radius of travel of a horse-drawn vehicle was, except where people were touring the country, fairly short; the drivers knew the location of all the crossings and were familiar with the train service over each. For these reasons, accidents were infrequent. If any additional warning was required, crossing bells, and, in some cases, watchmen and gates, were provided.

With the advent of the automobile the entire situation changed. Drivers were, in many instances, unfamiliar with the local conditions. The speed of the automobile at times equalled the speed of the train. Noises incident to operation of the automobile, especially of trucks, prevented the drivers from hearing the engine whistle, engine bell, and also the highway crossing bell far enough distant to stop short of the crossing.

According to the Bureau of Railway Economics statistics there were 252 507 grade crossings in 1921 and this number increased to 258 045 in 1924. During the same period 3 240 grade crossings were eliminated at an estimated cost of \$194 400 000, giving an average cost of \$60 000 per crossing. This is a very conservative figure.

The number of protected crossings increased from 40 779 in 1921 to 42 590 in 1924 and the number of unprotected crossings from 211 728 in 1921 to 215 455 in 1924.

According to 1917 Interstate Commerce Commission reports, 61 % of the casualties at grade crossings involved automobiles and by 1925 this figure had increased to 85 %. From 1917 to 1925 inclusive, there were approximately 12 000 people killed in grade crossing accidents in which automobiles were involved.

Recognizing these changed conditions, a special committee of the American Railway Association, Mr. James A. McCrea, Chairman (then General Manager of the Long Island Railroad), was appointed in 1915 to make recommendations as to more adequate protection. Realizing that one of the fundamentals is uniformity, so that the information regarding the conditions may be given to the drivers

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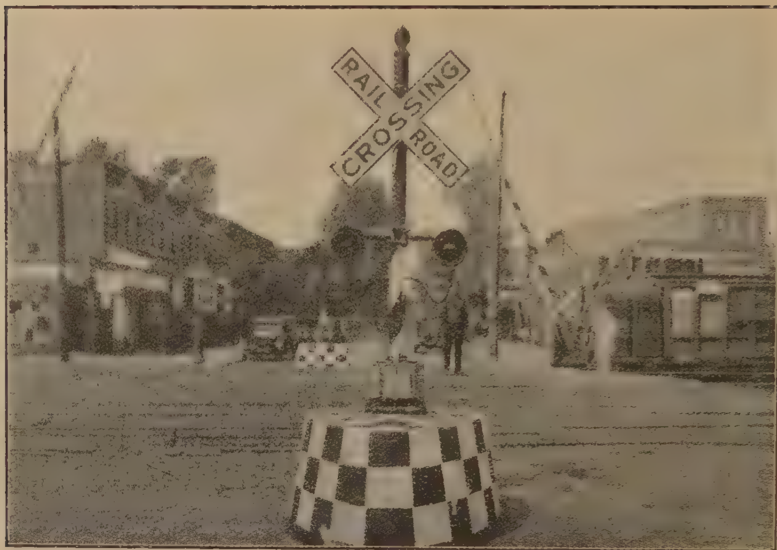
RAIL ROAD
CROSSING

Fig. 1.


RAILWAY CROSSING
TRAVERSE DU CHEMIN DE FER

Fig. 3.

Fig. 2.

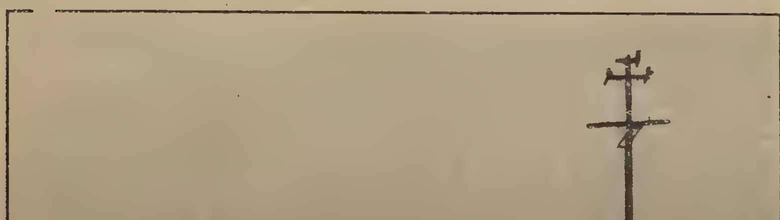

Fig. 4.

and pedestrians in the same way at all crossings the Committee recommended painting the crossing gates with black and white stripes; installation of standard approach signs at a given distance from the crossing (these now being the well-known circular disc with white background and black cross and border, showing black letters « RR » on the white background); the display of red lights toward vehicular traffic on crossing gates and in the hands of the watchmen, and the well-known stop sign to be used by the watchman during daylight. The report was adopted by the American Railway Association in 1916. The Committee also recommended regulations for the use of watchman's signal which were adopted by the American Railway Association. This Committee was continued from year to year as the Committee on Grade Crossing Protection and Trespassing, and, on 3 August 1921, Chairman C. L. Bardo requested the Signal Section of the American Railway Association to consider the question of standardization of mechanical or electrical devices installed at highway crossings as a substitute for crossing gatemen and flagmen, and make recommendations. Committee XX—Highway Crossing Protection, of the Signal Section, appointed 5 June 1921, Chairman J. B. Latimer, met in New-York on 18 November 1921, and reported to the Signal Section in March 1922. The Committee again reported to the Annual Meeting in June 1922. A part of the June 1922 report was approved by letter ballot.

In June 1922, the personnel of the Committee was changed and A. H. Rudd was appointed Chairman. At the 1923 Annual Meeting, the following resolution prevailed and was adopted as recommended practice :

« That an electrically or mechanically-operated signal used for the protection of highway traffic at railroad crossings shall present toward the highway, when indicating the approach of a train, the appearance of a horizontally swinging red light and/or disc. »

At the 1925 Annual Meeting, requisites for highway crossing signals were approved and adopted as recommended practice.

The requisites for highway crossing signals, as of date of issue of the chapter, are as follows :

Requisites for highway crossing signals.

1. *Aspect.* — An electrically or mechanically-operated signal used for the protection of highway traffic at railroad crossings shall present toward the highway, when indicating the approach of a train, the appearance of a horizontally swinging red light and/or disc.

2. *Location.* — The railroad standard highway crossing sign and the signal shall be mounted on the same post. Either a signal of the flashing light type or one of the wig-wag type may be used, but both should not be placed on the same post. No lights, markers or signs, other than those provided in the requisites, shall be placed on this post.

3. *Operating time.* — Automatic signal devices used to indicate the approach of trains shall so indicate for not less than 20 seconds [1] before the arrival of the fastest train operated over the crossing.

Flashing light type.

4. *Height.* — The lamp should preferably be not less than 6 feet nor more than 9 feet above the surface of the highway.

5. *Width.* — The two lamps shall be mounted horizontally 2 feet 6 inch centers.

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[1] Local conditions may require a longer operating time; however, too long an operation by slow trains is undesirable.

6. *Flashes.* — Lights shall flash alternately. The number of flashes of each light per minute shall be 30 minimum, 45 maximum.

7. *Hoods.* — Lamp units shall be properly hooded.

8. *Range.* — When lamps are operated at normal voltage, the range, on tangent, shall be at least 300 feet on a clear day, with a bright sun at or near the zenith.

9. *Spread.* — The beam spread shall be not less than 3° each side of the axial beam under normal conditions. This beam spread is interpreted to refer to the point at the angle mentionel where the intensity of the beam is 50 % of the axial beam under normal conditions.

10. — *Lenses or roundels.* — Size shall be 5 3/8 inches minimum, 8 3/8 inches maximum.

11. *Transmission values (for red lenses and roundels).* — Based on A. R. A. standard scale, should be 150 to 220 where plain cover glass with reflector is used; 220 to 300 where signals are used without reflectors or where the ribbed Spreadlite lens is used in front of the reflector.

12. *Short range indication.* — Signal shall display a satisfactory short range indication.

13. *Peep holes.* — Peep holes may be used.

Wig-wag type.

14. *Length of stroke.* — Length of stroke is the length of chord which subtends the arc, determined by the center of the disc in its extreme positions, and shall be 2 feet 6 inches.

15. *Disc.* — Size and painting of disc shall be as shown on A. R. A. Signal Section 1553.

16. *Number of cycles.* — Movement from one extreme to the other and back constitutes a cycle. The number of cycles per minute shall be 30 minimum, 45 maximum.

Flashing light and wig-wag highway crossing signals were presented at the 1927 Annual Meeting and are now recommended practice. In the flashing light type the lights flash alternately, giving the appearance of a swinging light, the number of flashes per minute being practically the same as the number of swings of the wig-wag disc. It will therefore be observed that all types of highway crossing signals give the same information in practically the same way, particularly at night when most needed.

Signals of the flashing light type have been favorably received in the eastern part of the United States, very few wig-wag signals being installed. In the western part of the United States, signals of the wig-wag type have been installed for many years and uniformity will be better attained by continuing the installation of this type. In the southern part of the country various types of signals have been used and a standard can only be attained by substituting either the flashing light or the wig-wag type; most roads are installing the former. In Canada the wig-wag type is used generally.

The Special Committee on Highway Crossing Protection has not made any recommendations as to the use or non-use of bells. Bells are more difficult to maintain in an operative condition than either the flashing light or wig-wag signal. If made to sound loud enough to be heard by the drivers of trucks and other heavy vehicles, they are an annoyance to the residents and, conversely, if not loud enough to be annoying, they cannot be heard by the drivers. Therefore, as a protection for automobile traffic, they are not of sufficient value to warrant their installation. However, where pedestrian traffic is heavy, especially in the neighborhood of schools, their use as an adjunct to the visual sig-

Fig. 5.

Fig. 6.

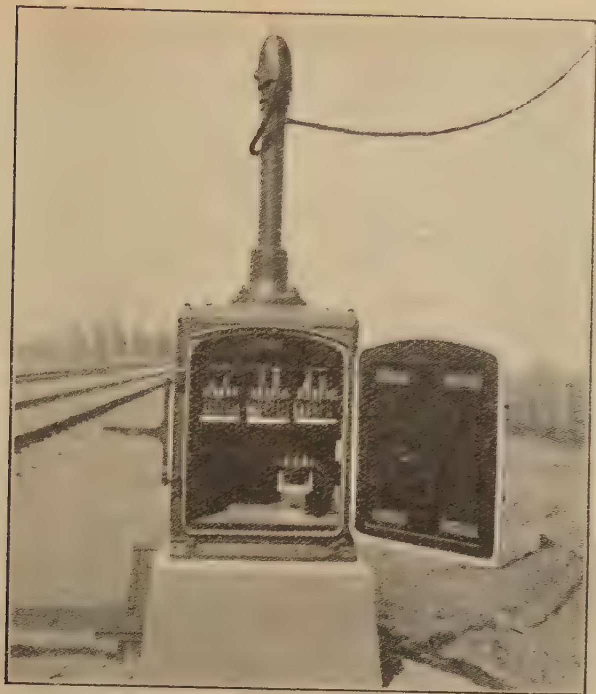

Fig. 7.

Fig. 8.

nal and for the sole purpose of warning pedestrians is in some cases justified. They need not be so loud as to cause annoyance.

The American Railway Engineering Association has recommended a standard crossbuck sign for use with signals of either the flashing light or wig-wag type. This sign is smaller and of different design than the more conspicuous crossing sign recommended for use where there are no signals to indicate the approach of trains. The recommendations of the Signal Section in regard to the height above the street level should be complied with.

One remaining problem, on which standardization is doubtful for a considerable length of time, is the location of these signals with respect to the vehicular traffic. Some Public Service Commissions desire them located in the center of the highway; in several States, the Highway Commissions refuse approval of such location on account of the obstruction in the highway. In other States, both the Highway Departments and the Public Service Commissions desire the signals located preferably to the right of the road. In cities and towns where traffic signals are located in the center of the highway, the center is probably the logical point to place the highway crossing signal, while in the open country, it would seem better to place them at the side of the road, preferably to the right where drivers naturally look for signs.

The theory of highway crossing protection is that a driver shall first be apprised by an approach sign (which may perhaps in the future be illuminated, as more and more highways are being lighted) that he is approaching a crossing; second, by some indication, preferably a reflecting sign close to the crossing, that there is no signal to indicate the approach of trains, and that he must by his own alertness protect himself; and third, by the display of flashing light or wig-wag signals at the crossing which indicate the approach of trains.

In a number of localities, the authorities have requested the substitution of highway crossing signals for crossing watchmen, on the basis that they are more reliable than the human agency and, in other localities, in place of gates, especially where such gates were operated only part time, recognizing that a raised crossing gate is one of the most insidious invitations to highway users to cross the tracks and that the crossing is particularly dangerous when the gates are unattended.

The practice of painting on hard roads two parallel lines with letters « R. R. » between them approaching the crossing, and stripes, similar to those on a crossing gate nearer the railroad, is highly commendable. This painting is being rapidly extended and is growing in favor. This marking is ideal but may be obscured by snow and it is not applicable to dirt roads. As an adjunct to other signals it is invaluable, and in some of the Southern States should, in many cases, be all the approach warning needed.

Many suggestions have been made that additional approach warning be given. Changes in the highway surface or alignment, obstructions in the center so that vehicles must slow down to drive around them, sharp reverse curves on both sides of the railroad and roughening the surface so that automobiles will be forced to reduce speed have been advocated. It is claimed that such devices would tend to concentrate the driver's attention on the immediate handling of his automobile and take his attention entirely away from the railroad crossing. It now is the consensus of the best informed that the safest crossing is the straight-away, smooth and level one so automobiles can be handled to the best advantage and which reduces the possibility of stalling on the crossing to a minimum.

Some States have laws requiring vehi-

cles to stop before crossing. However, away from towns and cities where the view is good, there is no need for such stop except for the purpose of obeying the law, and the tendency of the driver is to keep going, as no danger is involved.

It is good psychology that an unnecessary or unreasonable requirement is not obeyed as well as one wherein the reasonableness appeals to the public and, in many places, such laws cannot be obeyed without tying up traffic. Slowing down is better if drivers can be educated to shift to low gear to prevent possible stalling on the crossing.

An ideal arrangement of signals in addition to marking the highway would be the equipment of every motor vehicle, with a low light on the right side, shielded from view of approaching vehicles, with rays focused on or near the ditch, approach signs of standard size and appearance equipped with a reflecting surface, similar signs at the crossing, and in addition flashing light or wig-wag signals where local conditions warrant such protection.

The possibilities of the flashing light or wig-wag highway crossing signal are not yet generally recognized.

Several types of automatic gates are being exploited. Some have been installed. Their use introduces dangers. Highway crossing signals, on the other hand, do not drop on a vehicle or impose a sudden barrier as vehicles approach the crossing, or a barrier to prevent the driver of such vehicles from leaving the crossing. Remote control of gates has been advocated, but such control introduces dangers, whereas the remote control of crossing signals is feasible and would be, in many cases, advantageous. Highway crossing signals are operated in the majority of cases by track circuits on main tracks; most of those now in operation on double or more tracks being operated in the direction of traffic only, although in recent installations they are made operative by trains in either direction. Movements on sidings do not operate these signals, such movements being protected on most railroads by the trainmen acting as watchmen. Where switching is done within the circuit, the signals sometimes give misleading information. The operation of such signals nonautomatically, that is, controlled by a watchmen at some central point, and protecting five or six crossings on the approach of a train or when shifting is being done, is entirely feasible and, by such use, protection would be given for movements on sidings as well as on main tracks. Instead of having a signal start to operate at a fixed point, regardless of the speed of the train, the crossing watchman using good judgment can afford as much and perhaps more protection than an automatic device, and, at the same time, facilitate traffic on the highways.

Flashing light signals.

A flashing light signal consists of two lamps mounted 2 feet 6 inches center to center on a horizontal support arm fastened to a pipe or concrete post 6 to 9 feet from the ground.

Each lamp unit consists of a cast-iron case which houses the electric lamp. In the front of the case is a red lens and cover glass. A hood is placed above the cover glass to obscure the direct rays of the sun.

One signal is placed on each side of the track, facing travelers on the highway as they approach the crossing and either to the right or in the center of the road, as local conditions permit.

In some cases, where two or more streets intersect at or near the crossing, it is necessary to place additional lamp units to protect traffic on all streets.

When operating, the lights on each set of lamp units flash alternately and are timed so as to present the appearance of a horizontally swinging red light. The number of flashes per minute should be between 30 and 45.

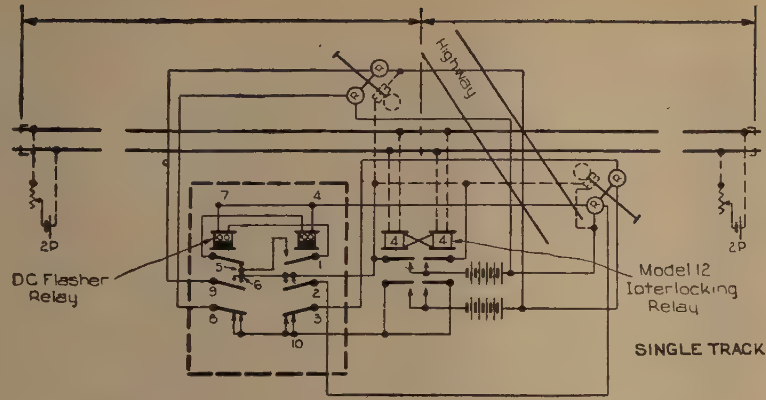

Fig. 9. — Typical circuits for light signals on single track.

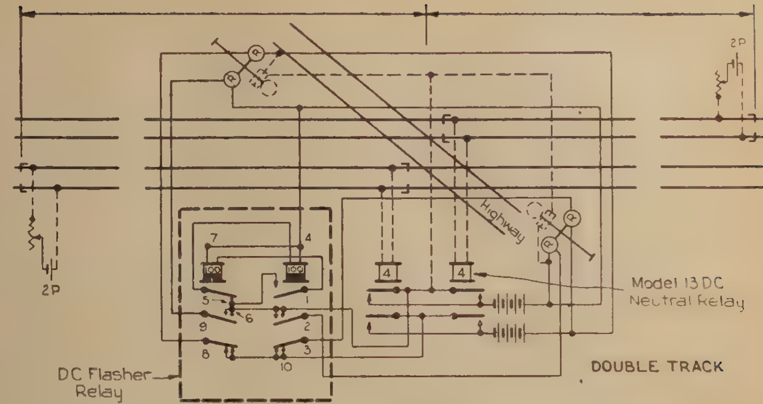

Fig. 10. — Typical circuits for light signals on double track.

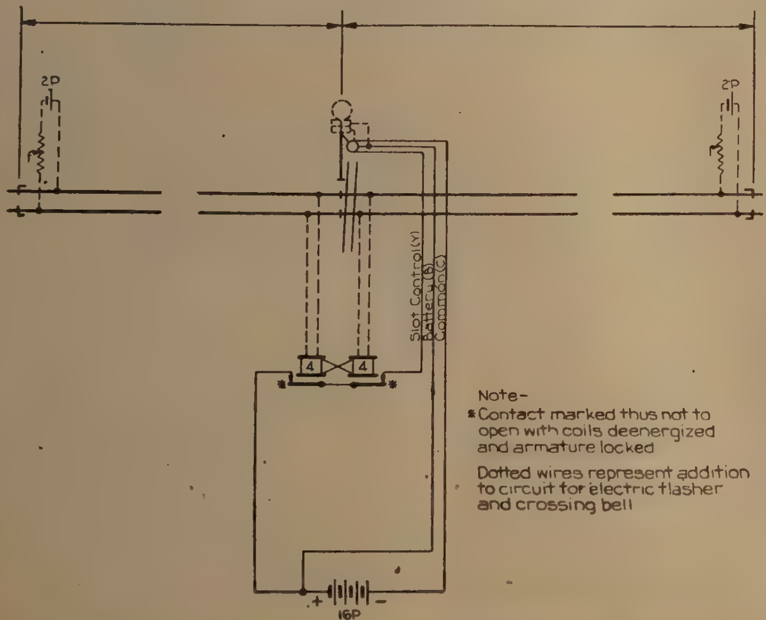

Fig. 11. — Direct current automatic flagman with direct current track.

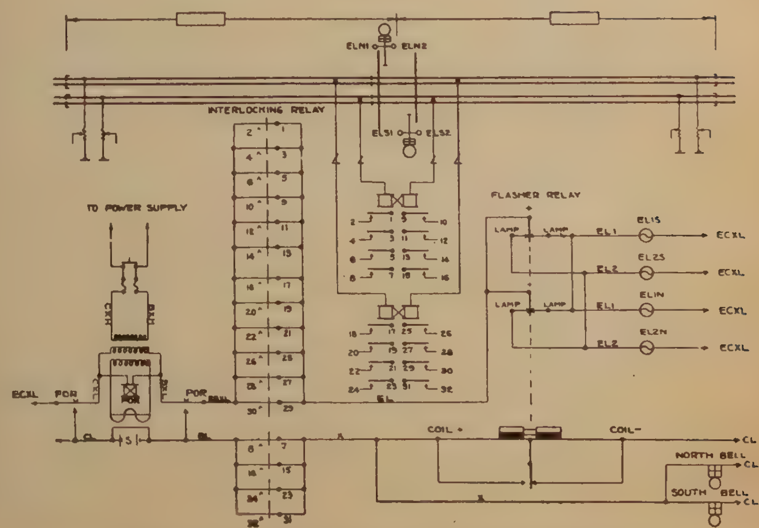

Fig. 12. — Typical circuits for flashing light signals.

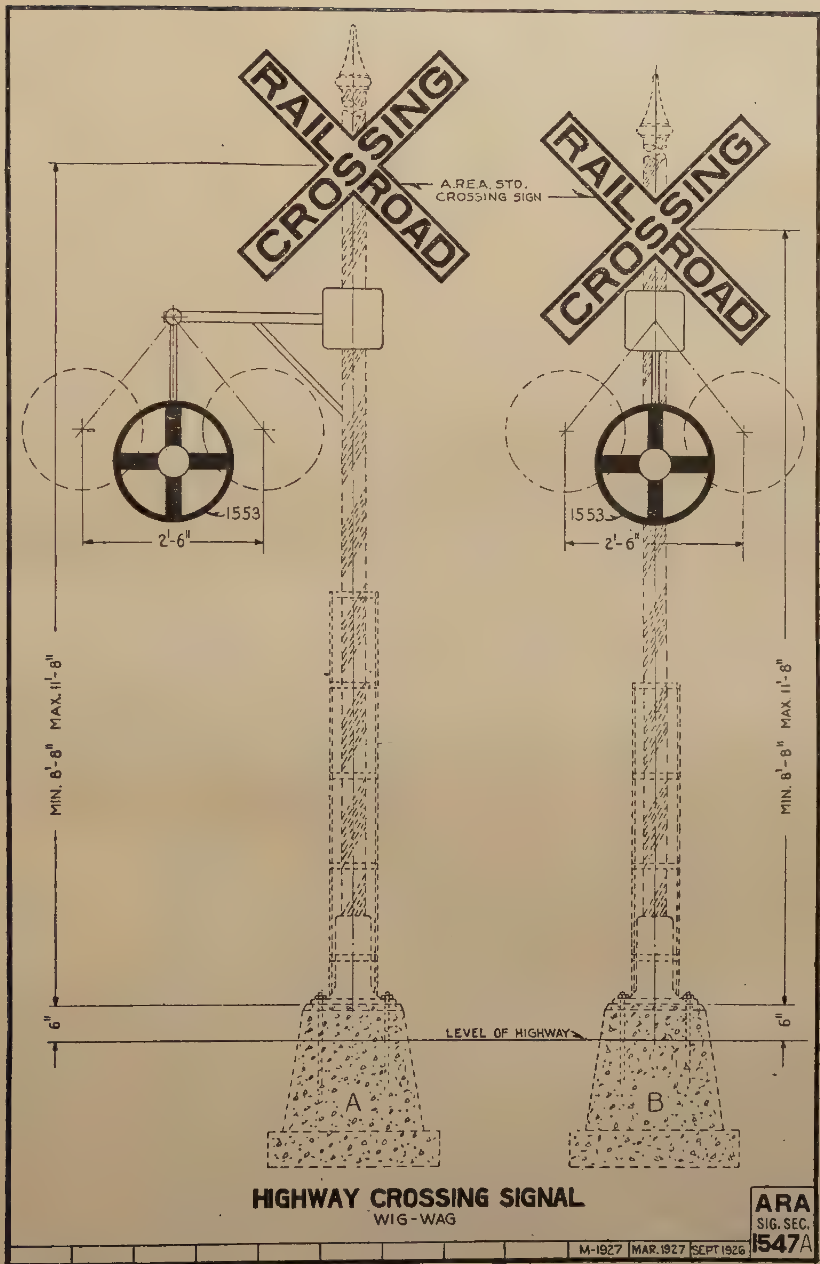
RAILROAD CROSSING
RAILROAD CROSSING
A.R.E.A. STD. CROSSING SIGN
1553
1553
2'-6"
2'-6"
MIN. 8'-8" MAX. 11'-8"
MIN. 8'-8" MAX. 11'-8"
6"
6"
LEVEL OF HIGHWAY
A
B
HIGHWAY CROSSING SIGNAL
WIG-WAG
M-1927
MAR. 1927
SEPT 1926
ARA
SIG. SEC.
1547A

Fig. 13.

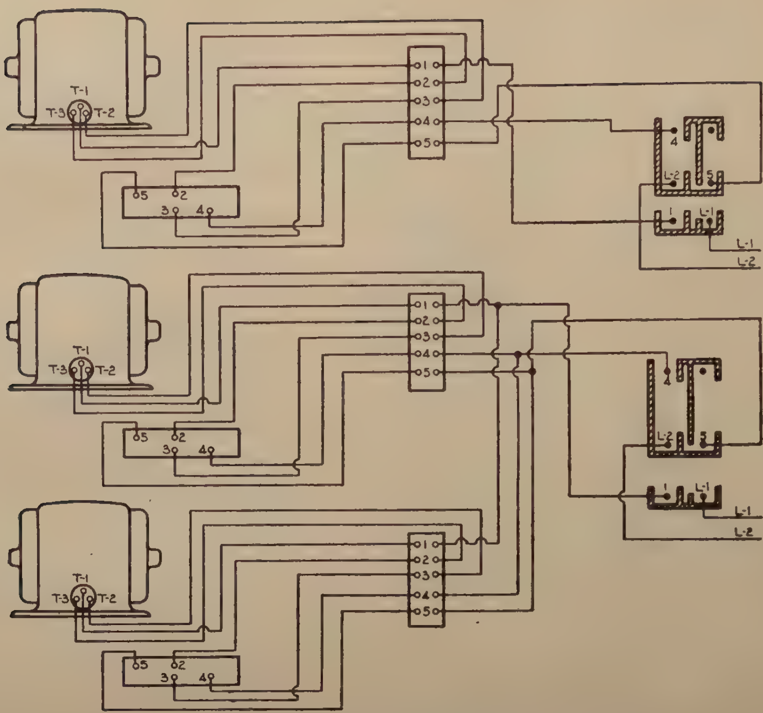

Fig. 14. — Wiring diagram for direct current or single phase alternating current motors.

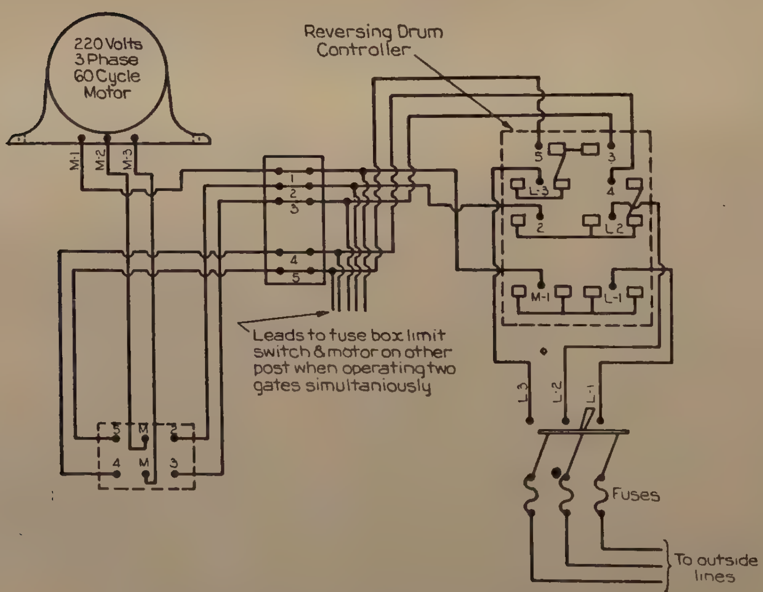

Fig. 15. — Wiring diagram for three-phase motor.

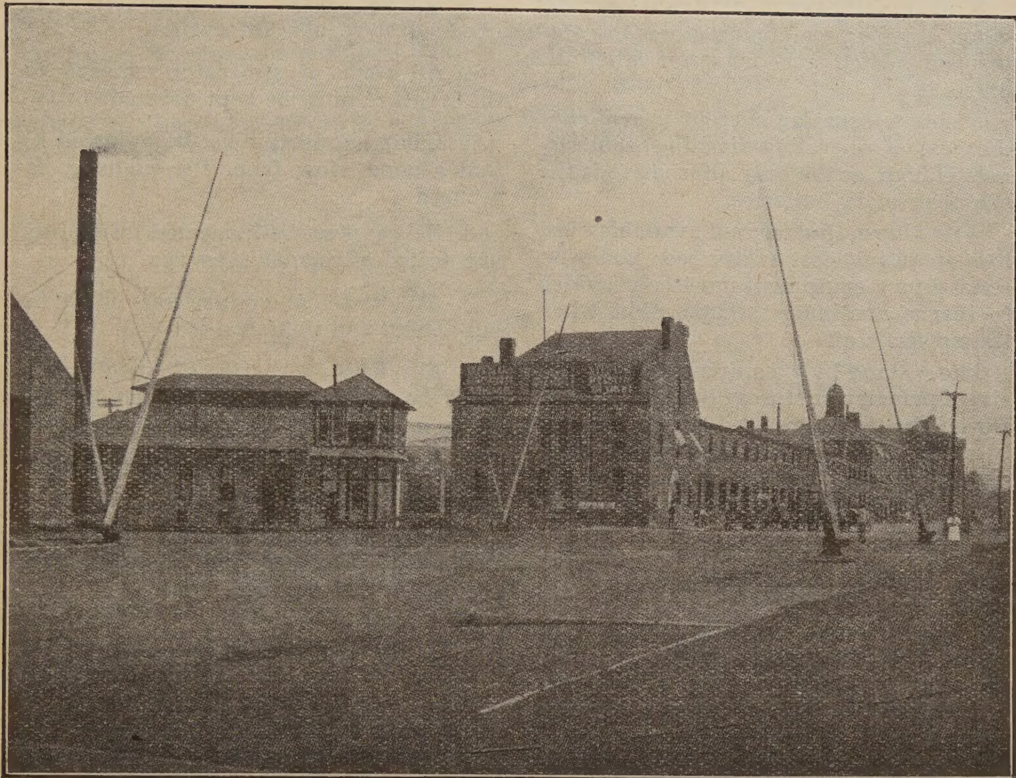

Fig. 16.

The flashing of lights alternately is accomplished by means of a flasher relay through which the light circuits are opened and closed alternately. The flasher relay is described in detail in Chapter VI : *Direct current relays.*

Current is fed to the lights through the flashing relay from another relay or controlling switch, the contacts of which are closed when a train is approaching.

The standard method of wiring requires that in case the flasher relay fails to operate, at least one light on each signal will burn constantly.

The signals may be controlled automatically or manually.

Probably the simplest and most common form of automatic control on single track is by means of an interlocking relay, both sides of which are connected to, or controlled through, track circuits extending in both directions the proper distance from the crossing. With this type of control, the signal operates from the time a train enters the operating section until the rear of the train passes the crossing. The directional operation is accomplished through the interlocking feature of the relay. The interlocking relay is described in detail in Chapter VI: *Direct current relays.*

There are several schemes of automatic control in use, some of which are illustrated in figures 9, 10 and 11.

A manually-controlled signal operates when crossing watchman closes the controlling switch and cuts out when he opens it.

Unless alternating current is available, the cost of operating flashing light signals is high, as the only alternative is the use of primary batteries.

With alternating current available, very low operating cost is assured; however, « stand-by » equipment must be provided to insure continuity of operation when the power is off.

The « stand-by » equipment may consist of primary or storage batteries. When storage batteries are used they are usually charged by what is termed the alternating current floating method, which method is described in Chapter IX: *Rectifiers*.

Wig-wag signal.

A wig-wag signal usually consists of a round disc fastened to one end of a rod, the other end being pivoted, and operated electrically. In the center of the disc a lamp with red cover glass is provided for the night indication. When operating, the disc swings horizontally.

There are two types of operating mechanisms used : motor-driven and magnetic. The magnetic type is favored by several roads on account of the absence of gears and other parts which require frequent replacements.

These signals are made to operate on either alternating or direct current at various voltages.

The control of the signal, other than local wiring, is the same as for flashing light signals.

Maintenance.

1. Voltage at lights must be maintained at prescribed value.

2. Battery and relay housing must be kept clean.

3. Wiring must be inspected and checked at regular intervals.

4. All parts of apparatus exposed to the weather must be kept painted.

5. Lamp supports must be adjusted so that a good view from the highway is secured.

6. Relays must be inspected frequently and tested at regular intervals.

7. All electrical connections must be kept clean and tight.

8. All moving parts of mechanism must be lubricated as specified by the manufacturer.

9. Operating mechanism must be kept in proper adjustment.

10. Signals should be tested or observed daily to insure reliable operation and record of performance made.

Highway crossing gates.

Where vehicular traffic is heavy, as on some city streets, manually-operated gates are used generally.

When a train is approaching the crossing, the watchman lowers the gates across the highway, thereby holding traffic until the train has passed over the crossing.

There are three types of gates in general use today : namely, pneumatic, mechanical and electric.

Pneumatic gates are operated by compressed air which is controlled by the watchman by means of valves. In most cases, the air is pumped by hand, but at busy crossings motor-driven compressors are used, or air is obtained from an air line used for other purposes.

Mechanical gates are either pipe, wire or chain connected to operating levers or cranks.

Electric gates are operated by individual electric motors which are control-

led by hand switches or other controllers. Typical circuits for electric crossing gates are shown in figures 14 and 15.

Crossing watchman's annunciators.

In order that the watchman may be warned of the approach of a train in ample time to lower his gates where the view of the railroad is obscured, annunciators are sometimes provided.

Annunciator may be a bell, or buzzer, manually controlled by a watchman at another street, or it may operate automatically when a train approaches. In some cases, visual indicator in addition to the bell or buzzer is provided.

CURRENT PRACTICE.

[625. 14. (.54)]

New pattern of permanent way on the Great Indian Peninsula Railway.

The attention of our readers is called to the new pattern of permanent way laid on the Bhor Ghat section of the Great Indian Peninsula Railway.

It is of interest as forming an intermediate type between the English design using bull headed rails and chairs, and the track laid with flat bottomed rails.

The 115-lb, rails are replaced by flat bottomed rails; the chairs by soleplates with side ribs between which the rails are held by two steel wedges.

Whilst this new arrangement is interesting it would appear to be more costly than the ordinary method of laying flat bott med rails.

The results given by this design in service will be published in due course in the *Bulletin.*